CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
520-770-3500
http://www.azgs.az.gov
inquiries@azgs.az.gov

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J. W. COOKSLEY, JR.
Geophysicist - Geological Engineer
APPLIED EARTH SCIENCES

J. W. COOKSLEY, JR.

PHONE
916—241-3167

BOX 1602
REDDING, CALIF. 96001

Tucson 622-8688

601 - 4th Avenue

or? 2749?

Box 928

85702

Don Bradley

New address & Phone Number July 1, 1973
2610 E. Grant Road
ph. 795-9790

J D Sell

AMERICAN SMELTING & REFINING COMPANY
Tucson Arizona

April 2, 1971

Mr. J. J. Collins
New York Office

Reflection Seismic Test
Sacaton Deposit - Pinal County,
Arizona

Dear Sir:

Enclosed is a proposal from Mr. J. W. Cooksley, Jr., to test the reflection seismic method at Sacaton. Mr. Cooksley has done extensive reflection work for Continental Copper on the Margaret Claim Group at our Superior East Project area. The results of that work have been made available to us by Continental Copper. Mr. Cooksley has, based on the results of several reflection traverses, prepared a contour map of the pre-mineral bedrock surface over a large portion of the Margaret Claim Group. We cannot evaluate the validity of his interpretation due to the absence of drill hole penetrations of the post-mineral sequence in this area.

As you probably know, both gravity work and refraction seismic work at Sacaton provided erroneous interpretations of bedrock depths. These two geophysical methods were inapplicable at Sacaton because the density and seismic velocity of the post-mineral conglomerates are very nearly as high as the older pre-mineral rocks. To be applicable in this enviornment, the refraction method would require shot to geophone separations of perhaps several miles. Separations of this magnitude would transect so many lateral velocity contrasts that ambiguities would be prohibitive. In contrast, the reflection method should be applicable for relatively small velocity contrast interfaces. Sacaton constitutes a good test area to evaluate reflection results because of the control provided by numerous drill holes.

Mr. C. K. Moss is in favor of conducting this test and would like to be present as an observer.

The cost of the test work will be $1,000., plus mobilization of approximately $100.. This is to request approval for Mr. Cooksley to conduct a reflection seismic test at Sacaton.

Very truly yours,

W. E. Saegart

W. E. Saegart

WES:van

cc: WLKurtz
JDSell
CKMoss

J. W. COOKSLEY, JR.
Geophysicist - Geological Engineer
APPLIED EARTH SCIENCES
BOX 1602 REDDING, CALIF. 96001
AREA CODE 916 — 241-3167

March 16, 1971

Mr. W. E. Saegart, Supervisor
Southwestern Exploration Division
American Smelting & Refining Co.
P. O. Box 5747
Tucson, Arizona 85703

Reference: Proposal to conduct reflection seismic geophysical work near Casa Grande, Arizona.

This letter constitutes a proposal to conduct reflection seismic geophysical exploration, consisting of a feasibility-type of program at the subject site. This work will be directed toward delineating the top of premineral rocks, measuring the depth of the discontinuity which separates these rocks from the overlying younger conglomerate unit. Velocity analysis will be performed on the reflection records using a technique which employes the use of a digital computer. A velocity log will be derived from this data.

We intend to use a detector spread employing 24 seismic detectors spaced 50 meters apart along a straight line. The length of this line would be about 3,800 feet. The cost of this work would be $1,000.00 plus 50¢/mi mobilization from Tucson to the site and back. We intend to use two vehicles on this project. The crew will consist of three men, one of which would be a geophysicist.

This office would supply the men and equipment for the seismic operations.

This office would be responsible for writing a report of investigation covering the proposed seismic investigation. Included in this report would be a location map and a seismic section drawn in the plane of the traverse.

We appreciate being considered for this assignment.

Respectfully submitted,

J. W. Cooksley, Jr.

J. W. Cooksley, Jr.

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

April 12, 1971

TO: W. E. Saegart

FROM: J. D. Sell

Re: REFLECTION SEISMIC SURVEY
MARGARET CLAIMS
SUPERIOR EAST PROJECT
PINAL COUNTY, ARIZONA

In talking with John Roscoe concerning the core from their drill hole M-1, it was also noted that their reflection seismic survey results were also available. Copy No. 3 of Cooksley's report and one folio set of sections were secured. Xerox copies have been made for the files and extra copy. Also included in the drill log for M-1. As reported in J. R. King's memo of March 5, 1971, Asarco interprets the core from M-1 to be andesitic basalt and probably low in the sequence of early volcanics. G. S. Barnett relogged all the M-1 cuttings and confirms that all units encountered in M-1 belong to the post-mineral sequence.

The folio sections for the seismic work are on file in the drafting department. *

James D. Sell

James D. Sell

JDS:sh

cc: WLKurtz w/ report by J.W.Cooksley, Jr.

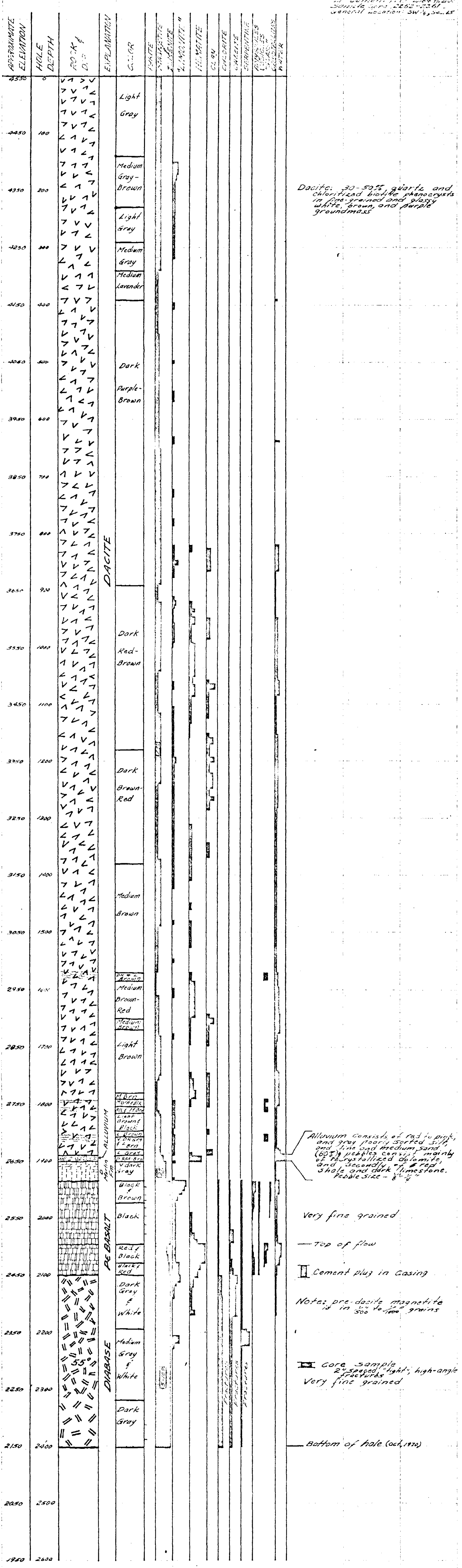
* folio Sections
Reflection Profile } in map rack.
Contour Map

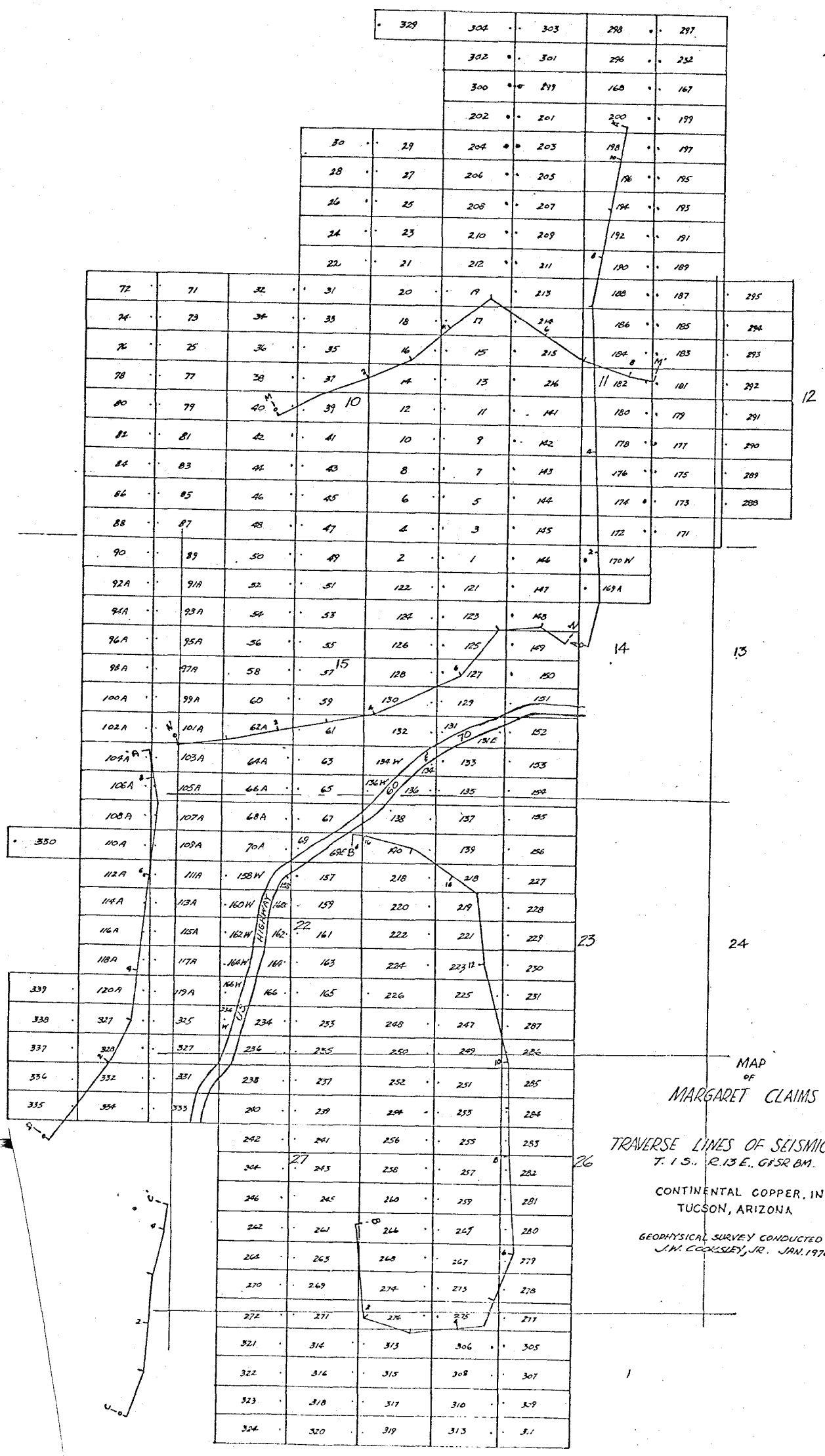
MARGARET-GROUP HOLE 1

Logged by G.J. Orback
for
Continental Copper, Inc.

Drilled Sept-Oct, 1970
Collar elevation 4550 ±

5⅝" Rotary Rock Bit
40' Casing to 2400
2½" Cement (1.5) 2384 to 2021
Sample Core 2262-2261
General Location: SW¼, Sec. 15





MAP
OF
MARGARET CLAIMS

TRAVERSE LINES OF SEISMIC SURVEYS
T. 1 S., R. 13 E., G&SR BM.

CONTINENTAL COPPER, INC.
TUCSON, ARIZONA

GEOPHYSICAL SURVEY CONDUCTED BY:
J.W. COOKSLEY, JR. JAN. 1970

REFLECTION SEISMIC SURVEY CONDUCTED ON THE MARGARET CLAIMS LOCATED ABOUT FOUR MILES NORTHEAST OF SUPERIOR, ARIZONA

Prepared by:

J. W. Cooksley, Jr.

J. W. Cooksley, Jr.
Geophysicist

June, 1970

Copy No. 3

CONTENTS

REFLECTION SEISMIC SURVEY

CONDUCTED ON THE MARGARET CLAIMS

LOCATED ABOUT FOUR MILES NORTHEAST OF SUPERIOR, ARIZONA

INTRODUCTION

The purpose of this seismic survey was to provide subsurface data in an area covered by a rather thick section of dacitic volcanics situated between Superior, Arizona to the southwest, and Miami, Arizona to the northeast. This program was directed primarily toward finding the contact of the dacitic volcanic section or the Whitetail conglomerate which are of Tertiary age with underlying igneous, metamorphic and sedimentary units, which range in age from early Tertiary (?) to Precambrian. Hereafter in this paper, the Tertiary volcanic section and the Whitetail conglomerate will be referred to as "superjacent units". Because the igneous, metamorphic and sedimentary units are the host rocks for the ore deposits at Superior and Miami, some effort was also directed toward delineating contacts and structure in the rocks underlying the superjacent units.

At the Margaret Claims, drilling data from five borings indicate that the depth of the pre-mineral units ranges from 1,500 feet to in excess of 4,000 feet. Only one of the five borings penetrated through the superjacent units and encountered potential host rocks for mineralization. Hence, the primary objective of the seismic exploration program was to provide data on which to base the mapping of the top of the potential host rocks.

Much has been written about previous exploration, mining activities, geology and ore deposits in the Superior and the Globe-Miami mining districts. The reader is referred to works by Peterson (1962), Hammer and Peterson (1968), Ransome (1903 & 1914), to mention only a few of the relevent published works, to obtain a more detailed description of these subjects. This report, being primarily a description of the findings of the reflection seismic program, will treat only those items which are most obviously and directly related to seismic interpretations and objectives of the seismic work.

A 24-channel, SIE P-11, reflection seismic system was used to record the seismic data. Approximately 14,850 meters (50,000 feet) of traverse line was executed in this project, and the seismic records were sent to a computing service to undergo some basic data enhancing.

Acknowledgement is hereby given to Mr. John Roscoe, Manager, Continental Copper, Inc., for his cooperation and help in the coordination of the field effort and in the compilation of this report. Acknowledgement is also given to Mr. Ray Larkin and to Mr. Bill Metz for their help in the field seismic operations.

GEOLOGIC SETTING

Sequence of Rocks

Dacite volcanic section. The prominent rock type in this section appears to be dacitic tuff. Vitrophyre is known to be locally present and basalt and andesite have been observed in the lower portions of the section. In the northwest area of the Margaret Claims, an east-dipping rhyolitic unit is exposed under the tuff.

Seismically, the bedding within the volcanic section appears as near horizontal reflections and they exhibit a good degree of continuity. The seismic velocity measured within the volcanics was about 6,000 feet per second.

Whitetail conglomerate. This unit, which commonly has a sandy and tuffaceous matrix, is derived mainly from local pre Tertiary outcrops and may be locally absent. It is Tertiary in age, underlies the dacitic volcanic unit, and rests on a Tertiary unconformity surface. Minute amounts of native copper have been observed in drill cuttings from this unit.

Seismically, this unit is normally expressed by relatively attenuated seismic waves, which are normally out of phase or, in some cases, locally denote lower velocity.

Intrusive rocks. This unit includes the Schultze granite and other related siliceous intrusive rocks which are believed to have been emplaced during Laramide times. The mineral deposits of the Superior and Miami Districts are believed to be closely related to this intrusive activity. These rocks intrude Paleozoic and Precambrian strata in the Superior District, and they intrude the Pinal schist of Precambrian age in the Miami District.

The seismic response of this unit is characterized by a wave which has considerably greater amplitude than the waves in the overlying conglomerate, and it has a lower frequency than the waves in the volcanic section. Seismic velocities were not measured in this unit, but they are believed to be well in excess of 10,000 feet per second in unaltered rock.

Paleozoic and Precambrian sedimentary units and diabase sill. These units are exposed in the Superior District to the west. The diabase of Precambrian age and the Martin Limestone of Devonian age, constitute the main host rocks for the mineralization at the Magma Mine. In the Superior District, these units generally strike northerly and dip to the east at 30 to 40 degrees. Attitudes taken in these formations where they crop to the north and to the east of the subject area, indicate the strong possibility that the structure is not simple and that reversals in attitude can be expected at the Margaret Claims.

In the seismic sections, it is thought that these units are present where numerous strong, parallel to subparallel, rather continuous, reflection events predominate. Velocities in these units were not measured.

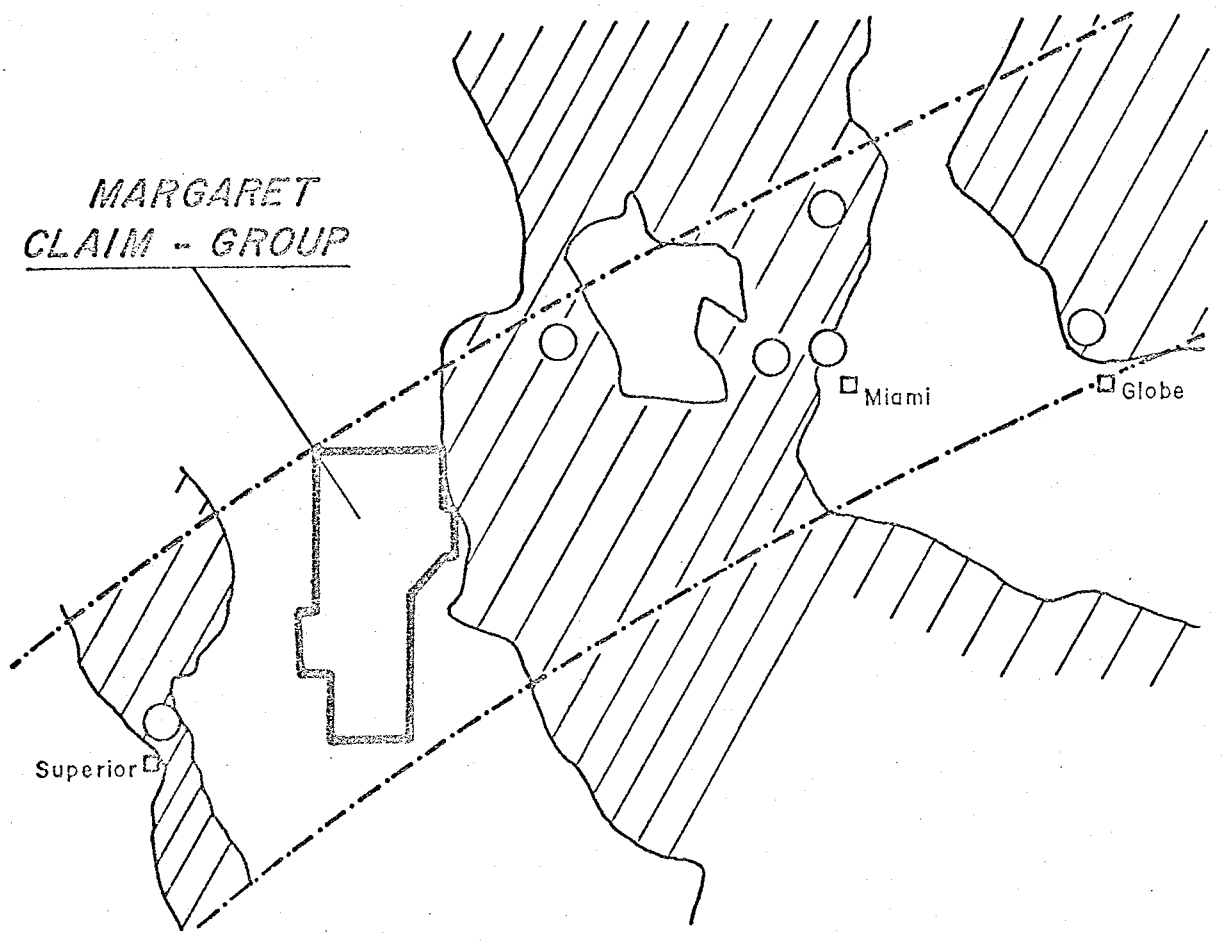


Figure 1:

Map of the Superior-Miami-Globe area depicting the approximate boundary of the Margaret Claim-Group. Also shown are the northeast-trending mineral belt of this region and and the areas where the host rock units are concealed under units of Tertiary and Quaternary age (unhatchured areas). Hatching represents areas of exposed host rock units. The dash-dot pattern outlines the mineral belt and the circles denote mines with productions in excess of $100,000,000.00.

Pinal schist. This unit crops out in the Miami District to the east. It is intruded by quartz monzonite porphyry, and is the host rock for several mineral deposits in this area. This unit has been described as a quartz muscovite schist and quartz muscovite chlorite schist, with indistinct to strong foliation.

Seismically, this unit is difficult to differentiate from the intrusive rock with the methods so far employed. Seismic velocities were not measured in this unit.

Structure

It seems probable that the Globe-Miami and the Superior mining districts lie on the interestion of two broad structural belts. One of these belts trends in a northeasterly direction and appears to constitute a zone of structural weakness that originated in Precambrian time. The mineral deposits appear to be related to this structural feature. The other structural belt is comprised of a set of north- to northwest-striking faults which cut and offset the east-striking faults. These faults are rarely mineralized, but they appear to constitute the main structural control accounting for graben-type structures which underlie the dacitic volcanic section.

Ore Deposits

The northeastward-trending belt about six miles wide, which encompasses the Superior District to the southwest and the Globe-Miami District to the northeast, passes through the subject area. It is believed that the northeast-striking faults in this area are deeply rooted structures and that they provide the plumbing system along which the mineralization was introduced.

At Superior, Arizona, the Magma Mine has produced nearly 1.5 billion pounds of copper. The main ore-producing structure in this mine is the east-trending Magma vein. In recent years, it has produced at a rate of from 30 to 40 million pounds of copper per year (Hammer, D.F. and Peterson, D.W., 1968). The Magma vein strikes east, and it cuts sedimentary strata of Paleozoic age and igneous, metamorphic, and sedimentary rocks of Precambrian age. To the east, the vein is offset to the north by north-striking faults. Also to the east, massive sulfide replacement is present in the Martin Limestone of Devonian age. Other mineralized structures of lesser importance have been explored and worked in the past. The principle trend to these structures is also easterly. The south side of the fault, along which the Magma vein has been emplaced, has been offset downward approximately 400 feet.

According to Peterson, N.P., 1962, the total production of this district had recently passed the billion-dollar mark. He further writes that nearly all deposits of this district that are of hypogene origin show the same trend as the general northeastward-trending belt.

PREVIOUS EXPLORATION

It is understood that the Margaret Claims, and in fact the whole area covered by the superjacent volcanic and congolmerate units, has been the subject of intense exploration on a number of occasions. This is a favorable place in which to explore for concealed mineral deposits, noting the fact that it is in the middle of a major northeast-trending mineral belt with large, productive mining districts situated both to the east and to the west.

Superior District

In 1874, silver mineralization was found in the Superior District. Since that time, this district has been the object of varying degrees of exploration activity. At present, a 3000+-foot shaft is being constructed at a site approximately two miles east of the Superior townsite and about 1.5 miles west of the southernmost Margaret Claims. It might be assumed that considerable exploration led to the justification of this project.

Globe-Miami District

Several exploration programs have been initiated in the last ten years in this district. Some of the results have led to the opening of the Bluebird and Oxhide Mines, the delineation of major reserves at Castle Dome, and the acquiring of large tracts of claims by several companies. While engaged in the field phase of this project during the months of January and February, 1970, at least two drilling rigs were observed on the large dumps north of the Miami townsite. This district, like the Superior District, has from time to time been the object of intensive exploration activity.

The Margaret Claims

Aerial Geologic Mapping

The most detailed geologic mapping of this area known to the writer is on a scale of 1: 24,000. The main features shown on this map are some differentiation of the volcanic units, faults, and some attitudes of bedding in the volcanics. The attitudes depict a broad synclinal structure, the axial plain of which is in the vicinity of Devil's Canyon.

Drilling

Several companies have conducted drilling on and in the vicinity of the Margaret Claims. Among these companies are Howe Sound, United Verde, Cibola Exploration, Superior Oil Co., Kerr McGee, and Inspiration Copper (?). The Howe Sound and United Verde borings were concentrated along the eastern edge of the dacite and the western portions of Sections 1 and 12, Township 1 South, Range 13 East. Two or three holes were drilled by Cibola Exploration along the highway which connects Superior and Miami. See Location Map, Fig. 2

Geophysics

It is known that magnetic and electrical geophysical methods have been used by other companies on the subject area. The results of this work are not available, but it is generally understood that although the geophysical work indicated some areas of possible interest, the reliability and resolution capability was seriously impaired because of the large depth to the potentially mineralized rocks.

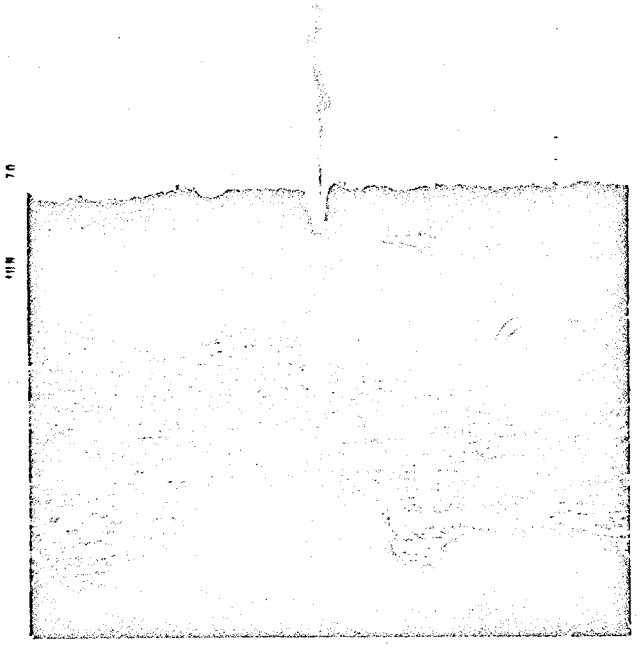


Figure 2:
Seismic shot.

AFFECT OF TOPOGRAPHY AND VEGETATION ON SEISMIC FIELD WORK

Although the difference in elevation between the highest and the lowest points in the seismic work is somewhat moderate, being only about 900 feet, the area which comprises the top of the dacite flows consists mainly of outcropping dacite. The vegetative cover, which consists mainly of various forms of cactus and rather short conifers, is moderate throughout most of the area, but is somewhat dense in some localities. The combination of the large areal exposure of rock in an uneven, hilly terrain disected by moderate to steep canyon walls, and the presence of a significant amount of vegetative cover, led to the conclusion that the existing roads provided the most efficient and feasible locations for the seismic traverse lines. In order to effect the overall efficiency gained by using the existing roads, some difficulties were encountered. These were:

1. An irregular configuration of seismic coverage.

2. Curvature in the seismic lines which necessitate additional care in the computing and interpretation of the seismic data.

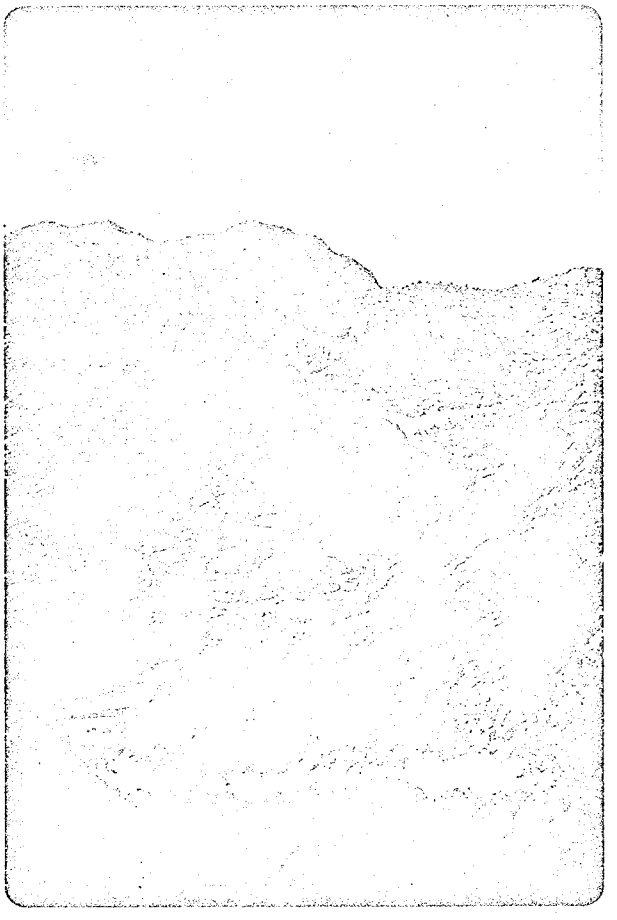


Figure 3:

Topography on Line D.

SEISMIC EXPLORATION

The seismic exploration program was based on the premise that a detectible seismic discontinuity was present at the base of the superjacent units. It seems reasonable to expect that the elastic properties of the superjacent units are sufficiently different from those in the underlying host units to constitute the potential for obtaining discernable seismic reflections. Local exceptions to this would be expected in areas of more intense faulting or in areas where this contact is deeply dipping.

On the seismic sections, elevation is marked to the left and the time in seconds is marked to the right. The elevation applies to all reflected events occuring at the main seismic discontinuity and above. Because the seismic velocity is much greater below the superjacent units, the reflections noted in the lower zone no longer relate to the elevation shown in the left column. Thus, the time in milliseconds of these events is shown in the column to the right for the purpose of computing the depth to any specific event. Tentatively, we suggest that a velocity of 12,000 feet per second be used in the rocks below the discontinuity.

It was found that the seismic response in the volcanic section, for the most part, differed substantially from the seismic response in the older units. In the volcanic units, moderate to rather strong, continuous, horizontal to near-horigontal reflection events were rather obvious. Generally, the seismic waves forming these events are rather sharp, having a relatively shorter wave length than the waves reflected by the older units. In the Whitetail conglomerate, the waves were commonly attenuated and the reflected events lost their horizontal to near-horizontal aspect. The typical seismic section in this project consisted of rather strong and easily correlatable horizontal responses from the volcanic section followed by a zone of variable thickness in which the waves were attenuated, this being the Whitetail conglomerate. This zone of attenuation was then followed by a series of stronger events, in many cases these events being as strong as those encountered in the volcanic section. These later strong events are those believed to be correlative with the top of the older host rock units. Correlation between traces of these later events yield a series of discontinuous lines which in general aspect form surfaces which are gently undulating to steeply dipping. Truncations and offsets of these events are more numerous than in the volcanic section and they are in many cases believed to be a result of faulting.

Paleozoic and Precambrian Sedimentary Section

In several of the sections a series of rather closely spaced, parallel to subparallel, strong reflected events are believed to be correlative with the Paleozoic and Precambrian sedimentary sections. Reflection events suggesting the presence of the Paleozoic and Precambrian sedimentary section appear in the following reflection sections:

Reflection Section B	0 to 4,000 feet and 15,000 to 16,000 feet

Reflection Section C	0 to 3,000 feet
Reflection Section D	0 to 4,000 feet
Reflection Section M	0 to 4,000 feet
Reflection Section N	4,000 to 6,000 feet

Faults and bedding can probably be shown in more detail if further, more sophisticated computer analyses are used.

Intrusive Rocks

An arch-shape configuration to the reflected events was noted in several localities in the reflection sections. This characteristic is being interpreted tentatively as possible intrusives, appearing in the following reflection sections:

Reflection Section A	Sta. 2,000 to Sta. 4,500 feet
Reflection Section B	9,000 to 13,000 feet -- time = 1.2 seconds
Reflection Section D	0 to 5,000 feet -- time = 1.2 seconds 6,500 to 8,000 feet -- time = 0.8 second
Reflection Section M	at Sta. 3,000 feet -- time 0.9 second
Reflection Section N	Sta. 0 to 4,000 -- time = 0.8 to 1.0 seconds Sta. 6,500 to Sta. 8,000 feet -- time = 1.0 seconds

Hydrothermally altered zones within and/or adjacent to the intrusives might be outlined with additional computer analyses and further interpretation of the existing seismic records.

Metamorphic Rocks

Those intervals along the traverses which are not covered under Paleozoic and Precambrian Sedimentary Section or under Intruisive Rocks are tentatively interpreted to be Precambrian metamorphic rock. The Pinal schist is the prevalent metamorphic rock in this area.

Geologic Structural Features

Faults

A comprehensive map depicting all the important faults in the rather large area encompassed by the Margaret Claim-Group cannot be drawn with the extent of seismic coverage thus far attained. As a matter of fact, the strike of many of the faults encountered along the seismic lines had to be inferred from the surface topography and the structural geology of the area as presently understood. Two main criteria were employed in mapping the faults -- first, the magnitude of disruption and displacement of the seismic events; second, the relevance the feature appears to have in the overall geologic setting. Two main systems of faults, based on the direction of strike, were interpreted in the Margaret Claim-Group.

A north-striking system of faults, which is probably the younger of the two systems, is apparently responsible for the graben-like structure which occupies the areas of the Margaret Claim-Group and Oak Flat. Of course, this structure has been subsequently filled with Whitetail conglomerate and the dacitic volcanic section. The top of the host rock units has been step-faulted downward to the west by two parallel, north-striking faults along the eastern edge of the subject area. From west to east, these faults are designated on the map as the Margaret fault and the Rawhide Canyon fault. The vertical throw on each of these structures appears to range from about 200 feet to perhaps more than 1,000 feet. The area lying to the east of the Rawhide Canyon fault and north of U. S. Hwy. 60 is probably the area with the thinnest section of superjacent units in the subject area.

A system of faults which strike N 75° E was inferred from the seismic data and topographic features. At least some of these structures are probably related to the northeast mineral trend in this region. The Magma fault might be represented by one of two fault structures encountered at the south end of Line C, or the fault at the south end of Line D. The south side of all three of these faults appears to be downthrown at least 200 feet. In Sections 22, 27, and 34, a scissors-type of movement appears on two of the northeast-striking faults. Here, to the west, the south block is downthrown, and to the east, the north block is downthrown.

Folds

The seismic data indicates that the Paleozoic strata are folded into a series of anticlines and synclines, and that dips of 30 degrees are probably common. Locally, the strata appear to be contorted into tight folds.

Topography of the Top of the Host Rock Units.

Northeast High Area.

The least depth to the host rock units is along the eastern edge of the northern half of the area covered by the Margaret claims, where the combined thickness of the Whitetail conglomerate and Tertiary volcanics ranges from a few hundred feet to about 2,000 feet. No seismic coverage was obtained east of the Rawhide Canyon fault, this being an area below which the top of the host rock units should be the least.

The area between the Margaret fault and the Rawhide Canyon fault was encountered in Lines A, B, M, and N, but Line B is situated in the southern half of the Margaret claims where the combined thickness of Whitetail conglomerate and Tertiary volcanics in the Margaret Claim-Group is in excess of 3,000 feet.

Host rock units in this area are comprised mainly of Pinal schist and quartz monzonite porphyry. Seismic data suggests a possibility of Paleozoic strata being present at the northeast corner of the Northeast High.

Central High Area.

Line N encountered a broad elevated area between the north end of Line D to the west, and the south end of Line A to the east. A saddle-like feature is interpreted just west of the Margaret fault. This saddle is probably related to a branch on the Margaret fault or to a structure which might account for the rather deep canyon to the northwest. A possible extension of the Central High area to the east appears between the Margaret and Rawhide Canyon faults. Another high, is represented by outcropping intrusive rock east of the Rawhide Canyon fault in Section 13 just beyond the eastern edge of the area mapped.

Seismic work shows a zone of diminished response and less continuity near the middle of the Central High. Zones of strong seismic signal flank the "diminished zone". The "diminished zone" is tentatively interpreted to be an intrusive mass which is flanked by Paleozoic strata.

Southern High Area.

An elevated area of host rock units is inferred from the seismic data obtained along Line B. This north-trending, one-half square mile area is situated in Sections 26, 27, 34, and 35. A saddle-like configuration near the top, and northeast-to east-trending spurs or ridges, might be related to the northeast-trending faults inferred at the south end of Line C. It is a moot point as to whether these features are related to the Magma vein-fault. An interesting local high was mapped adjacent to one of the faults on Line C.

The strong and "strata-like" events shown on the seismic records indicate that the Southern High is probably comprised mainly of Paleozoic sedimentary units.

Northern Low Area.

Seismic interpretation of Line M shows a large north-trending, canyon-like depression in the surface of the host rock units. This depression appears to widen and deepen to the north. Tennessee-Superior DCA #1, shown as D. H. 1 on the Contour Map, Plate 1, bears out the seismic interpretation. It is not known whether this feature was caused by erosion or faulting or both, but a similar north-trending feature, the Southern Low, is present south of U. S. Hwy. 60 and it is nearly colinear with the Northern Low on a bearing of about 20 degrees West.

Seismic readings indicate that stratified rock units, probably Paleozoic and Precambrian sedimentary formations, predominate in the Northern Low. Intrusive rock and Precambrian schist are indicated in the higher elevations to the east of the low.

Southern Low Area.

A rather deep, north-trending, canyon-like low in the surface of the host rock units is interpreted from the seismic readings acquired on Line B, the data from two exploration drill holes, and the areal geology east of the subject area. This depression appears to widen and deepen in a southerly direction. As mentioned above, this feature might be related to the Northern Low.

Schultze granite and Pinal schist are probably the predominant host rock units in the Southern Low. Line B, which is on the west side of the low, encountered weaker, discontinuous seismic readings which are interpreted to be from igneous and metamorphic units.

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Figure 4:

Dacitic volcanic section overlying Paleozoic sedimentary formations near Superior, Arizona.

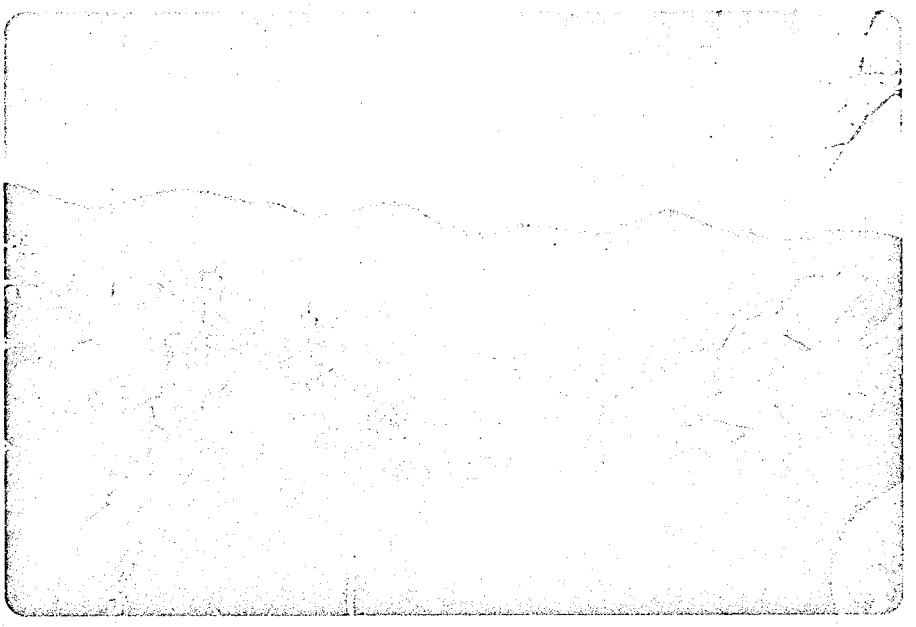

Figure 5:

Dacitic volcanic section overlying Schultze granite at the eastern edge of the Margaret claims.

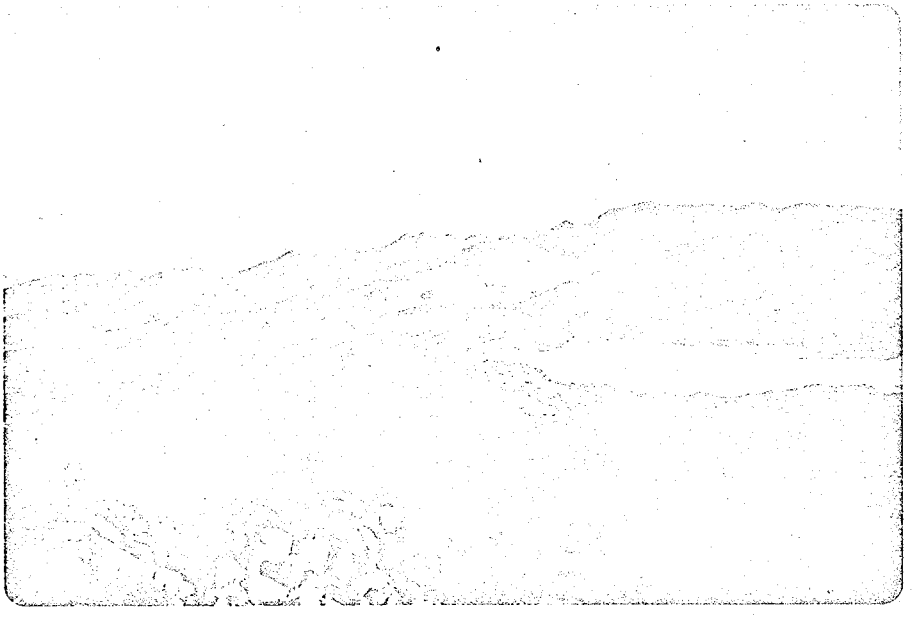

Figure 6:

Castle Dome Mine.

Figure 8:

Truck-mounted, 24-channel, seismic recording system in operation on Line D.

D. H. 1

TENNESSEE - SUPERIOR DCA #1

Dates drilled: May - July, 1964
Location: Cor. Melvin 1, 2, 7, 8

In Meters	In Feet	Description
0-140	0-460	Dacite, somewhat glassy, verging on welded tuff in places.
140-158	460-520	Glassy dacite -- vitrophyre.
158-228	520-745	Glassy dacite with felsite zones.
228-241	745-790	Felsite with glassy dacite.
241-306	790-1050	Glassy dacite.
306-415	1050-1360	Above, some red-brown volcanics present.
415-508	1360-1668	Felsite with volcanic and glassy zones.
508	1668	Lost circulation.
508-559	1668-1830	Felsite, glassy and red-brown volcanics (as above).
559-674	1830-2210	Andesite, amygdaloidal.
674-1225	2210-4011.5	Conglomerate. Fragments of granite, sandstone, diabase, quartzite, limestone, basalt, andesite, schist. Native Cu at 2885-2971 -- .02% Cu. Core at bottom: Cu = 0.020% to 0.004%.

El of Kelly = 4760 ft., 9" dia.

D. H. 2

TENNESSEE - SUPERIOR DCA #2

Dates drilled: July, 1964 and July, 1965
Location: Cor. AG 1, 2, 9, 10

In Meters	In Feet	Description
0-135	0-450	Dacite, somewhat glassy, pink-brown.
135-144	450-480	Dacite and andesite.
144-329	480-1095	Dacite, somewhat glassy, some andesite at 660, 780, and 1050.
329-363	1095-1210	Rhyolite and glass, interbedded -- some felsite (?)
363-402	1210-1270+	Dacite
402-459	1340-1530	Conglomerate with quartzite, sc, andesite, "pink igneous rock with biotite".
459-474	1530-1580	Schist -- 60%-70% red to gray sc., 30%-40% feldspar, quartz, felsite. 1532-1541 contains a little chrysacolla. Chlorite alteration at 1555, less sc down hole.
474-490	1580-1630	Granite.
490-500	1630-1670	Biotite granite with tr. of Cu.
500-505	1670-1685	Granite and granite-schist.
505-	1685-1772	Schist and Gneiss, much is brecciated, tr. Cu.

El. of Kelly 4720 ft.

D. H. 3

TENNESSEE - SUPERIOR DCA #3

Dates drilled: May and June, 1965
Location: Near Cor. Echo 14, 15, 16, 17,
NW 1/4, Sec. 23, Twp. 15, Rge 13E

In Meters	In Feet	Description
0-101	0-(330) 1400	Dacite, pink-gray.
101-110	(330-360)	As above, only finer-grained and lighter colored.
110-	(360-)	Dacite, darker.
427-441	1400-1445	Dacite and vitrophyre
441-459	1445-1505	Dacite and tuff. Some basalt in lower 15 ft.
459-741	1505-2430	Basalt.
741-915	2430-3000	Conglomerate

El. of Collar 4640 ft., 5-5/8" dia.

(South of Highway to Miami)

GEOPHYSICAL DIVISION

3422 South 700 West
SALT LAKE CITY, UTAH 84119

April 29, 1971

MEMO TO RALPH FALCONER:

REFLECTION SEISMIC SURVEY
SUPERIOR EAST, ARIZONA

Mr. Bill Saegart advises me that the Southwest Office is contemplating the seismic survey on the Superior East project by Jim Cooksley near the middle of May.

Will you plan to observe this survey. Also, you will be able to check with Jim Sell regarding your latest magnetic interpretation in relationship to Jim Sell's prevailing geologic interpretation.

C.K.M.

CKM:am

C. K. MOSS

cc: W. E. Saegart
J. D. Sell
W. G. Farley

May 3
Farley to handle the above work: to be started in next few weeks in Section 4

Section 5 to be roadwork.

JDS

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

May 17, 1971

TO: W. E. Saegart

FROM: J. D. Sell

RON GUILL

Re: COOKSLEY SEISMIC TRAVERSES
DACITE PLATEAU
PINAL COUNTY, ARIZONA

For expenditures of funds on State Lease lands in Sections 4 and 5 (T2S, R13E), it has been proposed that J. W. Cooksley, Jr., expand the seismic studies.

The following comments pertain to the study.

1) The lease date for Section 5 is May 29, 1971 and the affidavit must be filed in Phoenix prior to that date.

2) Some road work is being done at the present time for Section 5 but the difference between said expenditures and the total needed ($5,490.00) will be made up by seismic work. This will probably amount to some $2000.00.

3) The lease date for Section 4 is June 29, 1971 and the full expenditure of $5,910.00 is to be applied by seismic work.

4) Seismic line Margaret N-N' is over the drill hole location M-1 (Sec. 15, T1S, R13E). As recent re-drilling of the hole has verified, several rock type contacts not previously known, it will be necessary to re-evaluate the seismic information and perhaps re-shoot stations over the drill hole.

5) It is unknown at this time if we can secure up-hole velocity measurements by detonating a charge at the bottom of the hole M-1 in that the SLC lab requests the use of the hole for bottom-hole geophysical instrumentation.

6) As drill hole I-1 (Section 35, T1S, R13E) is reported to be in pre-mineral rock and as we have the reported log of the hole, it would be advantageous to run a line over the hole for correlation purposes. The road to the site is washed out for approximately one-quarter of a mile at the drill site end.

7) The attached map shows the State Lease Sections, the proposed work and the pertinant previous seismic lines.

8) Line over DCA-1

9) Cal Moss for visit on Wed-Thur (28-29?)

James D. Sell

James D. Sell

JDS:sh
attach.
cc: WLKurtz
RBCrist
RBCummings
WGFarley
Salt Lake Office/3
JWCooksley/3

AMERICAN SMELTING AND REFINING COMPANY
SOUTHWESTERN EXPLORATION DIVISION
P. O. BOX 5747, TUCSON, ARIZONA 85703

1150 NORTH 7TH AVENUE
TELEPHONE 602-792-3010

May 21, 1971

Mr. J. W. Cooksley, Jr.
P. O. Box 928
Tucson, Arizona 85702

Re: DRILL HOLE INFORMATION
SUPERIOR EAST PROJECT
PINAL COUNTY, ARIZONA

Dear Mr. Cooksley:

In following up the discussion of your seismic work for us, in which W. L. Kurtz, R. B. Crist, W. G. Farley and R. Guill were also present, the following information is submitted on three drill holes on the plateau area.

M-1 (SW¼, SW¼, Sec. 15, T 1 S, R 13 E)

0 - 1890	-	Dacite
1890 - 2428	-	Early Volcanics
2428 - 2920	-	Whitetail Conglomerate, fine-grained, few pebble zones, with mudstone.
2920 -+3200	-	Whitetail Conglomerate, mainly pebble conglomerate with minor (20%) fine-grained, mudstone, matrix.

This hole cored from 2400 to bottom by ASARCO. Minor core and all cuttings from surface to 2400 (by Continental Copper) is also available.

I-1 (SE¼ NE¼, Sec. 35, T 1 S, R 13 E)

0 - 1105	-	Dacite
1105 - 2939	-	Whitetail Conglomerate
2939 - 3240	-	Precambrian Diabase
3240 - 3475	-	Precambrian Schist

This hole totally corred by Inspiration and reported to us secondhand. I have no information as to the validity of the contact zones but feel they are probably correct.

DCA-1 (NW$\frac{1}{4}$ NE$\frac{1}{4}$, Sec. 3, T 1 S, R 13 E)

0 - 550	-	Dacite
550 - 2210	-	Early Volcanics
2210 - 4011	-	Whitetail Conglomerate

This hole air drilled by Miami Copper Company and Superior Oil Company. Geologic drill log is available and above contacts reinterpreted from the log.

James D. Sell

James D. Sell

JDS:sh

cc: WESaegart
WLKurtz
WGFarley
RBCummings
(extra copy to J. W. Cooksley, Jr.)

Preliminary Copy

May 1971

REFLECTION SEISMIC INVESTIGATION

OF SUBSURFACE GEOLOGY

AT THE SUPERIOR EAST PROJECT

GILA AND PINAL COUNTIES, ARIZONA

CONDUCTED FOR

AMERICAN SMELTING AND REFINING COMPANY

INTRODUCTION

This investigation is an expansion of a reflection seismic exploration program conducted on the Margaret claim-group during January - March, 1970 for Continental Copper, Inc. A report of investigation covering the initial project titled, Reflection seismic survey conducted on the Margaret claims located about four miles northeast of Superior, Arizona, was completed by this office and submitted to Continental Copper, Inc. in June, 1970. Since this time, American Smelting and Refining Company has taken over the exploration of the Margaret claims and some adjacent lands.

The seismic exploration in this area has been directed primarily toward finding the contact between the underlying pre-mineral assemblage of sedimentary, igneous and metamorphic rock units, and an overlying section of post-mineral volcanics and continental sedimentary units which measures in excess of 5,000 feet locally. Additional effort has been directed toward differentiating pre-mineral and post-mineral faulting, and in determining the type of rock present in the pre-mineral assemblage.

Much has been written about previous exploration, mining activities, geology and ore deposits in the Superior and the Globe-Miami mining districts. The reader is referred to works by Peterson, D. W. (1969), Hammer, D. F. and Peterson, D. W. (1968), Peterson, N. P. (1962), and Ransome, F. L. (1903 & 1914) which contain detailed descriptions of these subjects. This report, being primarily a description of the findings of the reflection seismic exploration, will treat only those items which are directly related to seismic interpretations.

Since the completion of the initial seismic work conducted for Continental Copper, Inc., two deep drill holes have been completed, and one is currently being drilled. The results of the drilling indicate that the

seismic work is in serious error west of the Margaret fault, but seems to be accurate to within ten (10) percent east of this structure. The Margaret fault is a north-striking normal fault, the west block down-thrown, which was interpreted from the seismic data. Apparently a large accumulation of Whitetail Conglomerate, a post-mineral, continental, sedimentary deposit, is present west of the Margaret fault. The velocity of this unit was greatly underestimated, thus resulting in an erroneously smaller depth calculation to the top of pre-mineral rock.

GEOLOGIC SETTING

Sequence of Rocks

		Lithology	Thickness	Velocity
POST-MINERAL	TERTIARY	Apache Leap Tuff -- predominantly dacitic tuff units, vitrified & devitrified.	1,000 to 2,000 feet	5,000 to 8,000 fps
		Unconformity		
		Older Volcanics -- predominantly andesitic to basaltic flow and tuffaceous units.	0 to 600 feet	10,000 (?) fps
		Unconformity		
		Whitetail Conglomerate -- continental conglomerate deposit in predominantly shaly to sandy matrix, well bedded to poorly bedded.	0 to 3,000 + feet	10,000 to 17,000 (?) fps
		Unconformity		
PRE-MINERAL	PENNSYLVANIAN	Naco Limestone -- Medium- to thin-bedded limestone that locally contains irregular nodules and layers of chert, and fissle shale sporadically interbedded with limestone. Bedding planes distinct and predominately flat, though some are wavy. Locally mineralized in the Globe area.	0 to 1,000 feet	12,000 to 14,000 fps (assumed)
	MISSISSIPPIAN	Escabrosa Limestone -- Thick- to thin-bedded limestone. Upper Escabrosa is medium- to thin-bedded and contains abundant chert and interbedded shale. Middle	400 to 500 feet	12,000 to 14,000 fps (assumed)

		Lithology	Thickness	Velocity
PRE-MINERAL		Escabrosa is thick-bedded and is cliff forming. Lower Escabrosa is thick- to medium-bedded. Mineralization occurs locally in Globe and Superior areas.		
PRE-MINERAL	DEVONIAN	Martin Limestone -- Alternating zones of thin- to medium-bedded limestone and dolomite. Thin beds of medium-grained quartzite, sandstone, and shale interbedded with limestone and dolomite in lower section. Upper limit of Martin defined by 10 - 30 feet of highly fissile calcareous shale. Medium-bedded dark-gray crystalline limestone is host rock for replacement ore bodies in Magma Mine and is locally mineralized elsewhere.	350 to 450 feet	12,000 to 14,000 fps (assumed)
PRE-MINERAL		Disconformity		
PRE-MINERAL	CAMBRIAN	Bolsa Quartzite -- Upper part - medium to fine grained quartzite that may grade locally to sandstone. Bedding distinct, medium to thick, generally even, locally undulating; crossbedding common. Lower part - heterogeneous clastic lithologies varying abruptly both laterally and vertically.	0 to 430 feet	
PRE-MINERAL		Unconformity		
PRE-MINERAL		Diabase -- Sills and dikes. Generally medium grained, locally course grained, aphanitic at		15,000 to 22,000 fps (assumed)

		Lithology	Thickness	Velocity
PRE-MINERAL	PRECAMBRIAN	chilled borders. Commonly, minerals moderately altered. Intrudes Troy Quartzite and older formations, and is depositionally overlain by Bolsa Quartzite.		
		Stratafied Precambrian Formations -- These include the Troy Quartzite (730 ft.), Basalt (max. 320 ft.), Mescal Limestone (350 ft.), Dripping Spring Quartzite (720 ft.), and the Pioneer Formation (305 ft.).	2425 feet	15,000 to 22,000 fps (assumed)
		Unconformity		
		Pinal Schist -- Quartz-muscovite schist and quartz-muscovite-chlorite schist. Well-developed to indistinct foliation that is slightly to intensely contorted. Pods, veins, and veinlets of white quartz locally abundant.		15,000 $\pm$ fps (assumed)

FINDINGS OF SEISMIC INVESTIGATION

The seismic exploration program was based on the premise that a detectible seismic discontinuity was present along faults and at the base of the superjacent units. It seems reasonable to expect that the elastic properties of the rock in proximity of faults and in the superjacent units are sufficiently different from those in the intact rock and in the underlying pre-mineral units to constitute the potential for obtaining discernable seismic discontinuities.

Correlation of Seismic Velocity with Geologic Units

The determination of average velocity is a rather complex procedure of interpreting reflection velocity analysis data as scanned with digital correlation methods. It has been our experience that using an analysis from only one shot point would invariably be misleading in at least one aspect and maybe in several. However, inspection of many velocity analyses simultaneously yields a more rational and complete interpretation of seismic velocity and geology.

Velocity analysis data indicates velocities in the Apache Leap Tuff range from 6,000 fps at the surface to as much as 8,000 fps at the base of the section. Interpreting from average velocity data, the seismic velocity of the Whitetail Conglomerate appears to be in the order of 10,000 fps to 12,000 fps. Velocities in pre-mineral assemblage rocks probably range from 14,000 fps to 20,000 fps where the rock is not affected by alteration or fracturing. The average seismic velocity which predominates at the base of the post-mineral sequence is about 10,000 fps, and this has been the velocity used to compute the depth to the pre-mineral rocks.

Mapping Faults

In this project, mapping faults is critically important in the interpretation of the seismic data. Pre-mineral faults do not transect the Whitetail Conglomerate or the Apache Leap Tuff. Hence the upward termination of these faults, if properly identified, can be used to interpret the discontinuity existing at the top of the pre-mineral assemblage. Post-mineral faults affect greatly the configuration of the unconformity at the top of the pre-mineral assemblage, so the movement on these structures must be known in order to map the top of pre-mineral rock.

Both pre-mineral and post-mineral fault structures are interpreted from the seismic data taken along the seismic traverses. An easterly strike is assumed on the pre-mineral faults and generally northerly strikes are assumed on the post-mineral faults. The basis for the strike of the pre-mineral faulting is the easterly strike of the Magma fault and the east-trending mineral belt which has been mapped and recognized by many

to encompass the major ore deposits at Superior, Arizona, to the west and the Globe-Miami area to the east. The northerly strikes, and the dips of the post-mineral faults are interpreted from the rather sparce seismic coverage at hand, from faulting mapped at the surface by Peterson, D. W. (1969), and from drill hole data made available to this office.

Seismic Section C-C'

Pre-mineral Rock Units

The elevation of the unconformity at the top of the pre-mineral rock ranges from about 400 feet at Station 1,500 down to about -300 feet at Station 3,500. The configuration of the unconformity if relatively flat.

Reflection discontinuities indicate the presence of stratified rock units immediately below the unconformity at the top of the pre-mineral units. These units are thought to be sedimentary formations of Paleozoic and Precambrian age, possibly intruded by diabase sills and dikes.

Pre-mineral Faults

At least three structures interpreted to be pre-mineral faults appear between Station 2,000 and Station 4,000 on Line C. The largest of these structures intersects the unconformity at the top of the pre-mineral assemblage at Station 3,500, displacing the unconformity about 200 feet downward on the south side. Below the unconformity, the seismic discontinuities, which probably represent bedding in Paleozoic and Precambrian strata, are displaced about 1,000 feet down on the south side. A possible speculation might be made concerning this structure, that is it might be the easterly extension of the Magma fault. There are two pre-mineral faults to the south of this structure; speculating again, possibly being correlative with the South Branch vein at the Magma mine or the Lake Superior and Arizona vein. A pre-mineral discontinuity to the north of the largest structure appears to have slight reverse movement. The elevation of the discontinuity at the top of pre-mineral rock at the largest structure appears to be about -250 feet.

Post-mineral Faults

Three post-mineral, normal faults intersect the top of the pre-mineral assemblage at, from south to north, Station 1,500, Station 2,600, and Station 3,400. The strikes of the faults at Stations 1,500 and 2,600 range from 20° to 30° west of north. The strike of the fault at Station 3,400 is about N35E. The intersection of these faults appear to form the corner of a block which has been down-thrown to the east. The largest of the pre-mineral faults appears to be intersected by the post-mineral fault at Station 3,400.

Seismic Section at Section 5

Pre-mineral Rock Units

Seismic readings indicate the elevation of the top of pre-mineral rock to range from 1,300 feet down to 800 feet along one set of reflection points, and from 1,300 feet down to 900 feet on another set of reflection points roughly parallel and about 500 feet to the east of the first set. Because of curvature in the line of seismic sensors, a northwest striking post-mineral fault was cut twice by both sets of reflection points. The top of pre-mineral rock is downthrown to the northeast from 100 to 250 feet or more.

Nearly-parallel lines of reflection events suggest that the pre-mineral assemblage is comprised of stratified rock units, probably in large part Paleozoic and Precambrian sedimentary formations. A sinuous, but fairly continuous reflection event can be traced discordantly across the stratified reflection events. This discordant event dips to the south and appears to be offset or at least influenced by pre-mineral structures. Tentatively, this event is interpreted to be the top or base of a diabase intrusive.

Pre-mineral Faults

Two pre-mineral faults are interpreted in the interval between Station 1,400 and Station 2,200 on one line of reflection points and in the vicinity of Station 1,600 and Station 2,000 on the other line of points to the east. The easterly strikes of these two structures were subsequently inferred from their intersections with the two lines of reflection points.

Post-mineral Faults

The main post-mineral structure is referred to above in the first paragraph under Pre-mineral Rock Units.

Seismic Section at I-1

Pre-mineral Rock Units

According to the seismic data, pre-mineral rock is encountered at elevations ranging from 2,300 feet down to 1,100 feet along this seismic section. Drill hole I-1 is at the south end of the section and here, the seismic data correlates well with the drill hole data. Between Station 0 and Station 2,500 and the north end of the traverse at Station 3,500, the unconformity is step-faulted upward to the north from an elevation of 1,300 feet to an elevation of 2,300 feet.

The random nature of the seismic discontinuities in the pre-mineral assemblage suggest that the Pinal Schist of Precambrian age, probably

cut by intrusives of Precambrian and Laramide age, is the predominant rock type.

Pre-mineral Faults

Two nearly-vertical pre-mineral discontinuities were plotted -- one near Station 1,200 and the other near Station 3,200. These structures are believed to be faults.

Post-mineral Faults

Post-mineral normal faulting offsets the top of the pre-mineral assemblage at Station 1,000, Station 2,000, Station 2,600 and Station 3,200. The northwest strike of the faults at Station 2,600 and Station 3,200 was ascertained by observation of their presence along two nearly parallel lines of reflection points. Displacement on both these faults is in the order of two hundred feet, the south side being down-thrown. Displacement on the other two faults appears to be less than 100 feet, again the south side downthrown.

Seismic Section at Section 4

Pre-mineral Rock Units

The top of pre-mineral rock is interpreted to be between elevation 800 and 1,700 along this traverse. Both pre-mineral and post-mineral faults are in evidence, the post-mineral faults having a large effect on the topography of the surface of the pre-mineral rock. A greater density and continuity of reflection events at the pre-mineral surface indicate the presence of stratified or tabular rock units. These units are believed to be sedimentary and volcanic units of Paleozoic and/or Precambrian age, but they might also be a series of gently-dipping, tabular disbase intrusions in Pinal Schist. These units appear to attain a thickness in excess of 2,000 feet at the south end of the traverse, but seem to pinch out to less than 500 feet at the north end. The rock underlying these units is interpreted to be Pinal Schist, possibly intruded by Precambrian diabase and Laramide granitic rock.

Pre-mineral Faults

Pre-mineral fault structures are interpreted at Station 2,800 and Station 4,500. Several northeast-trending, mineralized structures have been mapped in Pinal Schist where it crops about 5 miles to the east and northeast of this traverse (Peterson, N. P., 1961). The fault encountered at Station 2,800 appears to be vertical, the north side downthrown about 100 feet. The fault at Station 4,500 appears to dip very steeply to the north, the south side being downthrown about 100 feet.

Post-mineral Faults

Three post-mineral faults were mapped from the seismic data. Because of the lack of a parallel set of reflection points, the strikes of these structures are very questionable, being based on sparce geologic data. One rather large normal fault intersects the top of pre-mineral rock at Station 2,300. With a northwest strike being inferred on this fault, the southwest side is downthrown about 500 feet. Another rather large normal fault is at Station 4,000; the inferred strike is due north and the east side is downthrown about 300 feet. A fault with less movement was mapped at Station 5,200, the inferred strike being due north and the east side being downthrown about 100 to 200 feet. It seems quite possible that, the fault at Station 2,300 might be a branch of the large north-trending Margaret fault zone.

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✓ 7. Ransome, F. L., 1903, Geology of the Globe copper district, Arizona: U.S. Geol. Surv. Prof. Paper 12, 168 p.

✓ 8. _____, 1914, Copper deposits near Superior, Arizona: U.S. Geol. Surv. Bull. 540-D, p. 139 - 158.

EXPLORATION SERVICES DIVISION
3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

June 8, 1971

FILE MEMORANDUM

COOKSLEY SEISMIC PROGRAM
SUPERIOR EAST

In the latter part of May, Wayne Farley and I spent a day with Mr. Jim Cooksley who is conducting a contract seismic reflection survey for ASARCO on portions of the Superior East ground in Arizona. We visited his survey crew in the field, and had extensive discussions with him regarding his equipment, the computer handling of the data, and his own eye-ball interpretation of the computer seismograms.

Cooksley represents one of the very few geophysical contractors who offers seismic reflection service for mining exploration projects and who has had appreciable experience in this work. He utilizes convential 12-channel equipment which has seen common usage in the last decade in oil exploration. The seismic recordings are made on both photosensitive paper and magnetic tape.

The magnetic tape is sent to a Pittsburg computer service which handles the data in a conventional manner, such as has been used in oil exploration.

Cooksley appears to me to be conscientious, and sincere in his belief that his interpretations are meaningful. However, in view of the complex nature of the Superior section there is doubt in my mind as to a consistent accuracy in his correlation of seismic events with particular geologic horizons, or even in his correlation of seismic character from one record to another.

The computer service gives Cooksley a value for seismic velocities in the section, determined from an energy spectrum which is derived from the seismograms. (The velocity which one assumes for a given section determines the value of the depth determination for a seismic event). At hole MIA Cooksley interpreted the premineral rock to be at about 2000 feet by utilizing an intuitive value for velocity in the Whitetail. Drilling shows

the depth to be in excess of 3500 feet. Had Cooksley relied on the "computer velocity" he would have interpreted the depth at 3600± feet.

It is obvious that Cooksley's interpretation in uncontrolled areas should be taken with some skepticism, however, his results should be much more reliable when he uses his data to interpolate geology between drill holes reasonably close together. Also his interpretations should improve with experience in a given area.

I would personally like to see Cooksley test his work at Sacaton to determine whether he could "see" bedrock through alluvium and the Gila conglomerate.

C. K. Moss

CKM:am

C. K. MOSS

cc: W. E. Saegart
W. L. Kurtz
J. Sell
W. G. Farley
R. D. Falconer

AMERICAN SMELTING AND REFINING COMPANY
EXPLORATION SERVICES DIVISION
3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

C. K. MOSS
CHIEF GEOPHYSICIST

July 30, 1971

Mr. James Cooksley
601 North 4th Avenue
Tucson, Arizona

Dear Jim:

Our Jim Sell has made the suggestion that you advise him when your new hydrophone comes in. At that time you could consider shooting a velocity record on the present hole at Superior at whatever depth is available at the time.

The drilling would simply be interrupted long enough for your work.

Yours very truly,

ORIGINAL SIGNED BY
C. K. MOSS

C. K. MOSS

CKM:am

cc: W. L. Kurtz
J. D. Sell

EXPLORATION SERVICES DIVISION
3422 South 700 West
SALT LAKE CITY, UTAH 84119

August 13, 1971

Mr. Wayne Farley
Tucson Office

PROJECTED SEISMIC TEST
COOKSLEY SERVICE
SUPERIOR, SACATON

Dear Wayne:

In anticipation of possible seismic velocity tests in the near future, would you obtain the following data for Jim Cooksley and me.

1. Determine the estimated section that A-4 will have cut at Superior by the week of August 22. 3 or 4 morning of Aug 23.

2. Check with Norm Whaley and/or the Mining Department as to the accessibility into DH-119 at Sacaton.

Yours very truly,

ORIGINAL SIGNED BY
C. K. MOSS

C. K. MOSS

CKM:am

cc: W. L. Kurtz
J. D. Sell

1/3/72

J Cosbey intends to "multilith" the report so as to give a better image to Tucson office, NY office, Salt Lake office + others that read it.

If you see anything which might be changed, Jim would appreciate the comment prior to going to press.

JDS — I have read this but not checked the depths, figures etc in the tables.

The whole thing depends very strongly on the individuals (geophysicists) interpretation of the velocity profile (how the hell do you make the right curve) and to a lesser extent the interpretation of significant reflection from the "patterned" chart.

Is it an art or a science?

I'd still be rather skeptical of application. (Ann)

Preliminary Copy

COMPARISON OF SEISMIC EXPLORATION RESULTS WITH DATA ON THREE DEEP DRILL HOLES, SUPERIOR EAST PROJECT NEAR SUPERIOR, ARIZONA

Conducted for

AMERICAN SMELTING AND REFINING COMPANY

Prepared by

J. W. Cooksley, Jr.
Geophysicist

December, 1971

Copy No. 2

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COMPARISON OF SEISMIC EXPLORATION RESULTS

FROM DATA ON THREE DEEP DRILL HOLES,

SUPERIOR EAST PROJECT NEAR SUPERIOR, ARIZONA

INTRODUCTION

Experience gained since January, 1970, has shown that seismic reflections can be obtained from subsurface geologic units in the dacite plateau area east of Superior, Arizona. In this area, the older, pre-mineral rock units are covered by conglomerate and volcanic rock (the "dacite") of Tertiary age. The post-mineral section attains a thickness in excess of 6,000 feet at drill hole A-4 which is near the geometric center of the dacite plateau. About two (2) miles north of A-4, drill hole M-1 encountered 4,898 feet of the post-mineral section. To the east, however, particularly east of the Margaret fault, the post-mineral section is much thinner, e.g. about 3,000 feet in drill hole I-1 and about 1,500 feet in drill hole DCA 2.

The normal post-mineral sequence encountered in the drill holes completed to date consists of dacitic tuff which overlies an older volcanic section of andesitic flow and pyroclastic rock. The older volcanic unit is locally absent. These volcanic rocks commonly attain a combined thickness of 2,000 feet and they overlie the Whitetail Conglomerate which has a thickness of about 4,000 feet at drill hole A-4, but pinches out to thicknesses ranging from nil to a few hundred feet in a distance of only three miles to the west and to the east. The thickness of the Whitetail appears to be influenced strongly by block faulting occurring during the period of deposition.

At the western edge of the dacite plateau, the pre-mineral rocks consist of Paleozoic sedimentary formations and Precambrian sedimentary and volcanic strata which have been intruded by diabase sills. In the eastern portion of the dacite plateau the pre-mineral assemblage consists mainly of Pinal Schist and Schultze Granite.

Seismic reflections originate at the tops of the rock units of both the post- and pre-mineral assemblages. The better reflections are normally associated with the top of the Whitetail Conglomerate, the top of pre-mineral rock, and some of the units within the pre-mineral assemblage.

Unusually high seismic velocity in the Whitetail Conglomerate has led to erroneous seismic depth measurements to the top of the pre-mineral rock units underlying the dacite plateau. Computations of depths to pre-mineral rock made in this area during January-February, 1970, were based on an average velocity of 6,000 fps existing between the surface of the ground and

the top of pre-mineral rock. The velocity of 6,000 fps was derived from correlation of times of seismic events measured at Seismic Line A conducted on the Margaret Claim Group during January, 1970, with depth measurements made at drill hole DCA 2 located in Section 11, Township 1S, Range 13 E, near the eastern edge of the dacite plateau. Hole DCA 2 was used for the purpose of correlation because at the beginning of seismic exploration, DCA 2 was the only drill hole in the Margaret Claim Group that had encountered pre-mineral rock. It should be noted, however, that in DCA 2, only 200 feet of Whitetail Conglomerate was encountered in a total post-mineral section in excess of 1,500 feet.

Because subsequent drilling operations proved that the use of the 6,000 fps average velocity to pre-mineral rock would cause error in computing depth, a study was conducted to assess the effectiveness of the various seismic computing and signal enhancement techniques and a program was developed for the preparation, processing and computing of the seismic data. This program is subject to continuous scrutiny and development, but it has evolved into what is apparently a usable tool for mining geological investigations to find the depth and study the nature of pre-mineral rock which is covered by thick sections of barren post-mineral rock. Included in this program are velocity profiles, frequency analysis, digital filtering, and static and dynamic corrections. The program is built mainly around the velocity profile. The velocity profile depicts the seismic velocity as determined by a digital correlation technique at any time from 0 to 1.0 (or more) seconds on the seismic record. The time is corrected to datum. This phase of the program is used to:

1. effect the best dynamic correction for the seismic data,

2. pick seismic reflections and detect "multiple reflections" and "diffractions",

3. measure seismic velocity without the use of a drill hole.

DEFINITIONS

In the following discussions, the following definitions apply:

1. average velocity = the average velocity of a seismic wave from a point in the subsurface to the ground surface.

$$V \text{ ave} = \text{Depth/Time}$$

2. interval velocity = the average velocity of a seismic wave within a geologic unit(s).

$$V \text{ interval} = \text{length of interval/Time at bottom} - \text{time at top}$$

3. downhole (both average and interval) = velocities measured by lowering two seismic sensors down a drill hole and measuring the travel times of seismic waves originating at the surface near the collar of the drill hole.

4. a velocity profile at a shot point is a measure of apparent average velocity at a given record time. It is based on the standard formula

$$T^2 = T_0^2 + X^2/V^2$$

where T is two-way reflection travel time, T_0 is two-way vertical reflection time, X = shot point to sensor distance and V is average velocity. In practice, correlation across traces is performed for each T_0 at 20 ms increment at trial velocities from 1,000 to 19,000 fps in 100 fps increments. The X's are known and each trial velocity provides the appropriate T about which a small window of data is used in the correlation analysis. A measure of the correlation of the traces for each trial velocity and T_0 is displayed graphically. The three maximum peaks on each of these curves is indicated on a separate computer print and their value is listed. Theoretically the highest peak values correspond to the strongest signal energy and are indicative of possible reflections and the corresponding average velocity to the reflection. These velocity profiles are interpreted to provide a measure of average velocity at various reflection times and provide the dynamic corrections for the traces. (Courtesy of D. Fink, General Atronics Corporation, Philadelphia, Pa.)

COMPARISON OF SEISMIC DISCONTINUITIES WITH DRILL HOLE GEOLOGY

Drill Hole M-1

In summer, 1970, the M-1 drill site was chosen, based in large part upon the findings of the seismic work conducted during the preceding winter. M-1 was located in Section 15, Township 1 S., Range 13 E. Using the 6,000 fps average velocity derived from the measurements taken along Line A and from drill hole DCA 2, a depth of 2,400 feet was computed for the top of pre-mineral rock along seismic Line N in the vicinity of M-1. M-1 entered pre-mineral rock at a depth of 4,898 feet, twice the depth computed from the seismic work. Using the times of seismic events on Seismic Line N, and comparing these times with the depths of geologic units encountered in the nearby M-1 drill hole, the average velocity from ground surface to the top of pre-mineral rock was computed to be in excess of 10,000 fps instead of the assumed 6,000 fps. In addition to this, the interval velocity from the top of the Whitetail Conglomerate to its base is computed to be 13,000 fps.

Inspection of the cores from M-1 shows the Whitetail to be comprised of two (2) main rock-types. The upper section, a well-bedded siltstone section, probably possesses less velocity than the lower section, a poorly-bedded to non-bedded conglomerate section comprised mainly of gravel- to cobble-size fragments of Pinal Schist bound in a matrix which is dense, sandy, and well consolidated. The contact between these sections seems to be represented by a seismic event occurring at 0.720 seconds on the traces closest to M-1. See Plate 2, Appendix A. Comparison of seismic measurements with the drill hole data shows interval velocities of 8,200 fps and 15,850 fps for the upper section and the lower section of Whitetail respectively. The rather substantial section of the low-velocity upper unit strongly affects the average velocity and hence results in a somewhat large reflection time to the pre-mineral rock at M-1.

A reworking of the seismic field data on Line N was initiated using the more advanced procedures of the computing program discussed in the Introduction of this report. Included in these procedures was detailed study of velocity and frequency, and the employment of digital filtering. The improvement in record quality led to a revision of the interpretation of the top of pre-mineral on the seismic records from about 0.800 second to 1.060 seconds (Plate 2, Appendix A). Table I summarizes the comparison of depth data at drill hole M-1.

Velocity profiles from Shot Points 1 and 2 on Line N indicate the average velocity to the top of pre-mineral rock is about 10,100 fps. See Plate 1 and 2 in Appendix B. Using this velocity and a time of reflection of 1.060

seconds, less 0.100 second to correct from datum to ground surface, the depth to pre-mineral is :

$$\frac{1.060 \text{ sec.} - 0.100 \text{ sec.}}{2} \times 10{,}100 \text{ fps} = 4{,}800 \text{ feet.}$$

This compares well with the 4,898-foot depth ascertained in M-1. Table I summarizes the comparison of depth data 1) as originally computed, 2) as computed using the average velocity indicated by the velocity profile, and 3) as found in M-1.

GEOLOGIC UNIT	DEPTH (in feet)		
	Seismic		Drill Hole
	Ave. Vel. = 6,000 fps from DCA 2	Ave. Vel.= fps from Vel. Profile	M-1
Top of upper Whitetail Conglomerate (0.580 sec)	1,740	2,280 ave. vel.= 7,500 fps	2,428
Top of lower Whitetail Conglomerate (0.740 sec)	2,220	2,960 ave. vel.= 8,000 fps	3,000 ±
Top of pre-mineral assemblage (0.960 sec)	2,880	4,800 ave. vel.= 10,100 fps	4,898

Table I. Comparison of depths to tops of upper Whitetail Conglomerate, lower Whitetail Conglomerate and pre-mineral rock as determined seismically (using average velocity = 6,000 fps and using average velocity from velocity profile) with those determined in drill hole M-1.

Drill Hole I-1

A north-south seismic traverse, Seismic Line I-1, was located in the eastern portions of Section 35 and 26 of Township 1 N., Range 13 E. One of the main purposes of this traverse was to provide seismic data which could be checked against the drilling data obtained from the drill hole I-1, which is located at the south end of the seismic line. The travel times of the seismic discontinuities interpreted to be the tops of Whitetail Conglomerate and the pre-mineral assemblage were ascertained from the seismic record section, and, using the velocity profile from the shot points closest to drill hole I-1, the average velocities to these discontinuities were interpreted. See Plates 3 and 4 in Appendix B. Using average velocities of 7,000 fps at the top of the Whitetail Conglomerate and 10,600 fps at the top of premineral diabase, the depths of the reflection events representing the tops of the units were computed and found to correlate well with the drill hole data. See Plate 3, Appendix A.

Thus good correlation of the seismic data with the drill hole data was achieved by using the velocity profile to estimate the average velocities which were used to compute the depths to the tops of the Whitetail Conglomerate and the pre-mineral rocks. No drill hole data was used to compute these depths. The following summarizes the comparison of depth data at drill hole I-1:

GEOLOGIC UNIT	DEPTH	
	Seismic	Drill Hole I-1
Top of Whitetail Conglomerate	1,260 feet	1,105 feet
Top of pre-mineral assemblage	3,070 feet	2,939 feet

Table II. Comparison of depths to tops of Whitetail Conglomerate and pre-mineral rock as determined seismically with those determined in drill hole I-1.

Drill Hole A-4

A seismic reflection event interpreted to be the top of pre-mineral rock takes place at 0.900 seconds in the part of Seismic Line C closest to drill hole A-4. See Plate 4, Appendix A. At this point Seismic Line C is nearly 1,000 feet west of A-4. Using the old estimated average velocity of 6,000 fps, the initial estimate for the depth to pre-mineral rock in this area was about 3,000 feet. Knowing this estimate was wrong, it was decided to send the data back for additional computing work to obtain a more detailed and comprehensive analysis. The velocity profile showed the average velocity in the 0.900-second portion of the record to be about 14,200 fps. See Plate 5 and 6 in Appendix B. This seemed to be erroneously high in view of the 10,200 and 10,150 fps average velocities to the top of pre-mineral rock computed at drill holes M-1 and I-1. Hence, the average velocity of about 10,000 fps to the top of pre-mineral at drill holes M-1 and I-1 was noted, and increased to 11,000 fps for the purpose of recomputing Line C and estimating the depth to pre-mineral at A-4. The 11,000 fps velocity yields a depth of about 4,400 feet. If the 14,200 fps velocity from the velocity analysis were used, the depth would be 5,700 feet.

The 11,000 fps velocity was chosen as a compromise between the 10,000 + fps velocities at M-1 and I-1 and the 14,200 fps velocity indicated from the velocity profiles from Shot Point 8, a shot point about 1,000 feet from A-4. In retrospect, it is obvious that the 14,200 fps from the velocity profile was more accurate and that the compromise led to an erroneous depth calculation.

At the completion of drilling on A-4, a downhole seismic survey was conducted to a maximum depth of 4,490 feet. Lack of cable prevented going deeper. At 4,490 feet, the average velocity to surface is about 13,100 fps and the interval velocity in the section of Whitetail Conglomerate between 4,340 and 4,490 feet is about 17,600 fps. This data tends to substantiate velocity profile data which shows an average velocity of 14,200 fps at a depth of 6,000 feet and a 17,500 fps velocity through the total Whitetail section.

The following summarizes the comparison of depths of pre-mineral rock at drill hole A-4 and Seismic Line C.

GEOLOGIC UNIT	DEPTH		
	Seismic		Drill Hole A-4
	Ave. Vel.= 11,000 fps from M-1 & I-1	Ave. Vel.= 14,200 fps from vel. pro.	
Top of pre-mineral rock	4,400 feet	5,700 feet	6,300 feet

Strong slanting events are present in the vicinity of A-4 at 0.900 to 1.000 seconds on the seismic record. The upper limit of these are interpreted as the top of pre-mineral rock. These events might be diffractions off a fault structure instead of being reflections from the pre-mineral surface. If this is the case, the pre-mineral surface is likely to be lower, perhaps the event at 0.950 seconds -- 0.850 seconds when corrected from datum to ground surface. Using an average velocity of 14,200 fps to this event:

$$\frac{0.850 \text{ sec.} \times 14{,}200 \text{ fps}}{2} = 6{,}040 \text{ feet}$$

as the depth to pre-mineral rock.

SEISMIC VELOCITY MEASUREMENTS

Three methods have been employed for determining the average velocity from the ground surface to the top of a geologic unit represented by a seismic discontinuity. In order of their use on this project, these methods are:

1. Correlation of seismic events with drill hole data and computing velocities using the depth (distance) data from the drill hole and the time data from the seismic records. It should be noted that the time of an event recorded on the seismic record should be divided by two (2) because it represents a two-way (down and up) travel time.

   $$\text{Thus: } V_{ave} = \frac{\text{Depth}}{\text{Time}/2}$$

2. Interpretation of velocity profiles.

3. Downhole surveys conducted on drill holes accomplished by applying an energy source at the surface near the collar of the hole, and recording the seismic waves with sensors lowered down the hole. A one-way travel time is recorded seismically, and the depth is measured on the sensor cable.

   $$\text{Thus: } V_{ave} = \text{Depth}/\text{Time}$$

VELOCITY BY CORRELATION OF SEISMIC EVENTS WITH DRILL HOLE DATA

The first step in computing seismic velocity by correlating seismic events with drill hole data is to pick the events on the seismic record which represent geologic contacts or features which can be identified in the drill hole. This

correlation is shown on the records in Appendix A. Lable the geologic interpretation of these events and note the depths at which these features were encountered in the drill hole. Next, record the two-way travel time of the seismic waves (from the source at the ground surface to the discontinuity + from the discontinuity back up to the sensors at the ground surface) after employing normal static and dynamic corrections and insuring that the datum corrected times are corrected to the time which represents the drill hole elevation. At the drill holes discussed in this report, the time correction to collar elevation is -100 ms for M-1, -70 ms for I-1, and -100 ms for A-4.

To compute the average velocity to the correlated feature,

$$V\ (ave) = \frac{D}{T/2}$$

Where: D = depth in distance
T = two-way time

To compute the interval velocity between two (2) correlated features,

$$V\ (int) = \frac{D_2 - D_1}{(T_2 - T_1)/2}$$

Where: D_1 = depth to upper unit
D_2 = depth to lower unit

T_1 = two-way time to upper unit
T_2 = two-way time to lower unit

The table on the following page, Table IV, presents the velocity data acquired by the correlation method at M-1, I-1 and A-4.

SEISMIC VELOCITY MEASUREMENT FROM CORRELATION OF SEISMIC & DRILL HOLE DATA

GEOLOGIC UNIT	DEPTH Top	DEPTH Base	TIME AT Top	TIME AT Base	AVERAGE VELOCITY Top	AVERAGE VELOCITY Base	INTERVAL VELOCITY	
Line N - Drill Hole M-1								
Dacite	0	1,890	0	.480		7,900	7,900	1,890/.240 = 7,900
Older Volcanic	1,890	2,428	.480	.580	7,900	8,400	10,760	2,428/.290 = 8,400 538/.050 = 10,760
Upper Tw	2,428	3,000	.580	.720	8,400	8,100	7,150	3,000/.360 = 8,330 572/.070 = 8,200
Lower Tw	3,000	4,898	.720	.960	8,100	10,200	17,200	4,900/.480 = 10,200 1,900/.120 = 15,850
Total Tw	2,428	4,898	.580	.960			13,000	2,470/.190 = 13,000
Line I-1 - Drill Hole I-1								
Dacite	0	1,105	0	.360		6,130	6,130	1,105/.180 = 6,130
Tw	1,105	2,939	.360	.580	6,130	10,150	16,650	2,939/.290 = 10,150 1,834/.110 = 16,650
Line C - Drill Hole A-4								
Dacite	0	2,133	0	.400		10,640	10,640	2,133/.200 = 10,640
Tw	2,133	6,300	.400	.800	10,640	15,750	20,835	6,300/.400 = 15,750 4,167/.200 = 20,835

SEISMIC VELOCITY MEASUREMENT FROM CORRELATION OF SEISMIC & DRILL HOLE DATA (CONTINUED)

GEOLOGIC UNIT	DEPTY		TIME AT		AVERAGE VELOCITY		INTERVAL	
	Top	Base	Top	Base	Top	Base	VELOCITY	
Line C - Drill Hole A-4 (continued)								
If pre-mineral is at 6,000 feet instead of 6,300 feet of depth,								
	2,133	6,000	.400	.800	10,640	15,000	19,300	
If pre-mineral is at 5,700 feet of depth,								
	2,133	5,700	.400	.800	10,640	14,200	17,800	
ALTERNATE TIME FOR TOP OF PRE-MINERAL, USE TIME = 0.850								
	2,133	6,300	.400	.850		14,850	18,550	6,300/425 = 14,850 4,167/.225 = 18,550
	2,133	6,000	.400	.850		14,110	17,200	6,000/425 = 14,110 3,867/.225 = 17,200

Table IV.

VELOCITY FROM INTERPRETATION OF VELOCITY PROFILES

Velocity profiles from seismic shot points near drill holes M-1, I-1 and A-4 are in Appendix B. Several parameters are considered in the interpretation of these profiles, both geophysical and geological. Interpreted curves representing the average velocity have been drawn on the velocity profiles. These curves have not been adjusted to correlate with either the drill hole information or with each other. Several points and some sections of curves occupy positions away from the interpreted curve. This results from many possibilities, e.g. diffractions, reflected refractions, multiple reflections, low velocity zones in the rock...

Depths to discontinuities can be computed by multiplying the time of the event on the seismic record by 1/2 and by the average velocity indicated on the velocity profile at the time of the event.

$$D = (T/2)V\ (ave)$$

Using the velocity profile data, interval velocities are computed with the same formulae as used in the correlation with drill hole method; however, the depth (or distance) data are computed using the average velocity from the velocity profile and the two-way travel time on the seismic record instead of acquiring the depths from drill hole data.

The following presents depth and interval computations at the three drill holes.

N -- M-1

Time to Tw upper = 0.680 - 0.100 = 0.580 sec.

Vel at 0.680 from velocity profile = 7,400 fps

$$\text{Depth} = \frac{0.580}{2} \times 7{,}400 = 2{,}140 \text{ feet}$$

Time to Tw lower = 0.840 - 0.100 = 0.740 sec.

Vel at 0.840 from velocity profile = 8,000 fps

$$\text{Depth} = \frac{0.740}{2} \times 8{,}000 = 2{,}960 \text{ feet}$$

Time to pre-mineral = 1.060 - 0.100 = 0.960 sec.

Vel at 1.060 from velocity profiles = 10,100 fps

$$\text{Depth} = \frac{0.960}{2} \times 10{,}100 = 4{,}800 \text{ feet}$$

N -- M-1
(continued)

Interval velocity for Tw upper

$$\frac{2,960 - 2,140}{(0.740 - 0.580)/2} = \frac{820}{0.080} = 10,240 \text{ fps}$$

Interval velocity for Tw lower

$$\frac{4,800 - 2,960}{(0.960 - 0.740)/2} = \frac{1,840}{0.110} = 16,700 \text{ fps}$$

Interval velocity for Tw upper & lower

$$\frac{4,800 - 2,140}{(0.960 - 0.580)/2} = \frac{2,660}{0.190} = 14,000 \text{ fps}$$

I-1 -- I-1

Time to Tw = 0.430 - 0.070 = 0.360 sec.

Vel at 0.430 sec. from velocity profile = 7,00 fps

Depth = $\frac{0.360}{2}$ x 7,000 = 1,260 feet (1,105 ft from drill hole)

Time to pre-mineral = 0.650 - 0.070 = 0.580 sec.

Vel at 0.650 from velocity profile = 10,600 to 11,000 fps

Depth = $\frac{0.580}{2}$ x 10,600 = 3,070 feet

Interval velocity for Tw

$$\frac{3,070 - 1,260}{(0.580 - 0.360)/2} = \frac{1,810}{0.110} = 16,400 \text{ fps}$$

C -- A-4

Time to Tw = 0.500 - 0.100 = 0.400

Vel at 0.500 from velocity profile = 10,500 fps

Depth = $\frac{0.400}{2}$ x 10,500 = 2,100 feet

Time to pre-mineral = 0.900 - 0.100 = 0.800

C -- A-4
(continued)

Vel at 0.900 from velocity profile = 14,200 fps

$$\text{Depth} = \frac{0.800}{2} \times 14{,}200 = 5{,}700 \text{ feet}$$

Interval velocity for Tw

$$\frac{5{,}700 - 2{,}100}{(0.800 - 0.400)/2} = \frac{3{,}600}{0.200} = 18{,}000 \text{ fps}$$

VELOCITY FROM DOWNHOLE SURVEY

One-way travel times are recorded between a seismic source at the surface near the collar of the hole and the sensors which are in the hole at a known depth. This is the only method of the three discussed in which a positive identification of the depth of a given seismic event can be made. The downhole survey on A-4 yielded the following:

1. a positive identification of reflections originating in the upper 60 % of the Whitetail section.

2. the average velocity between depths ranging from 3,500 feet to about 4,500 feet and the ground surface.

3. interval velocities over three 150-foot sections of the drill hole between depths of 3,500 feet and about 4,500 feet.

Actually, two (2) sensors and a thermometer were lowered down A-4. Although only one sensor was needed to furnish average velocity, a second sensor spaced 150 feet up the hole was used to compute an interval velocity over the 150-foot increment. See Appendix C.

The following table summarizes the average velocities and the interval velocities measured.

Depth	Time	V(average)	ΔT	V(interval) $= 150/\Delta T$
3,640 feet	0.284 sec	12,800 fps		
3,990 feet	0.310 sec	12,900 fps	8.5 ms	17,600 fps
4,490 feet	0.343 sec	13,100 fps	8.5 ms	17,600 fps

Table V.

The thermometer was a maximum-reading type, capable of recording to 200 degrees F. It was lowered to a 4,500-foot depth. The thermometer registered 165 degrees when taken out of the hole.

CLOSING STATEMENT

In summary, comparison of the seismic discontinuities with the drill hole data obtained at M-1, I-1 and A-4 shows that using an erroneous average velocity will result in faulty seismic depth computation. It is felt that

selectively using the three different approaches to determine average velocity used in this study will result in accurately assessing this parameter. The three methods of obtaining average velocity are:

1. Interpretation of velocity profiles

2. Correlation of times of seismic events with drill hole data

3. Downhole shooting to obtain one-way travel times

Comparison of the seismic and drilling data further shows:

1. Average velocity can be accurately assessed from the velocity profile.

2. Extrapolating average velocity determined from drill hole data can lead to error (as in the case of drill hole A-4) because the average velocity will vary with the variation in the amount of faster vs slower rock material in the overlying units. Nevertheless, additional experience has and will lead to more effective use of average velocities derived from both drill hole correlation and down hole shooting methods.

J. W. COOKSLEY, JR.
Geophysicist - Geological Engineer

APPLIED EARTH SCIENCES
BOX 2749 TUCSON, ARIZONA 85702
AREA CODE 602 · 622-8668

6 January 1972

American Smelting and Refining Company
Southwestern Exploration Division
P. O. Box 5747
Tucson, Arizona 85703

Attention: James D. Sell

Reference: Billing for Phase II of downhole and reflection seismic investigation of subsurface geology at the Superior East Project in Gila and Pinal Counties, Arizona.

LINE C - Rework

Computer Service @ cost		$ 360.00
Geophysicist @ $25.00/hour	8 hours	200.00
Assistant Geophysicist @ $12.50/hour	8 hours	100.00

A-4 DOWNHOLE - Field

Geophysicist @ $25.00/hour	6 hours	150.00
Seismic Operator @ $12.50/hour	16 hours	200.00
Field Assistant @ $8.00/hour	16 hours	128.00
Downhole System @ $400.00/day	1 day	400.00
Drill @ $50.00/day	1 day	50.00
Vehicle @ $15.00/day, 15¢/mile		
2 vehicles for 2 days, 300 miles		150.00
Per Diem - 3 man crew - Motel	$30.00	
Meals	70.00	100.00

VELOCITY STUDY OF SUPERIOR EAST PROJECT

Geophysicist @ $25.00/hour	32 hours	800.00
Assistant Geophysicist @ $12.50/hour	8 hours	100.00
Reproductions, typing		55.00
	TOTAL INVOICE	$2,793.00

OK for Payment
Superintendent M.A-0010-04
James D. Sell

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

February 17, 1972

Memorandum

TO: W. L. Kurtz

FROM: J. D. Sell

Final Report
Seismic Exploration Results
J. W. Cooksley, Jr.
Superior East Project
Pinal County, Arizona

Attached are four copies (WLK, File, JDS, Salt Lake City?) of Cooksley's final report on the seismic work conducted on the project over the three deep holes I-1, M-1A, and A-4. As verbally reported previously, the work was originally scheduled for a comparison data report based on reported geologic contacts to J.W.C.,Jr. with his seismic interpretations on drill holes I-1 and M-1A. The second part of the report was to interpret the seismic results of A-4 and predict the geologic contacts based on the two previous drill holes. The interpretation results were not obtained prior to the completion of A-4 and, thus, this final report was rescheduled into the attached format.

As can be seen, the seismic results suggest that geologic contacts can be interpreted from the data. Specifically, however, it was fully determined that interval velocities continually change in all the units in the project area and, thus, average values cannot be used in projection of data away from a specific shot point at this time. To interpret contacts and depth, it is necessary to construct two profiles or curves; 1) the basic seismic line of the shot point data, as shown in Plate 1 - Appendix B, and the contact interpretation from the profile with the event time calibration; 2) the highly interpretive velocity profile, Plate 1 - Appendix C, which is based on the energy spectrum at any time. Using the contact time in step 1 and transferring to step 2 curve, the contact time can be converted to velocity. Calculation of the depth to the time-contact event can then be made.

The seismic data is apparently definitive at this time, although it is based on interpretive results to a high degree.

To further check the interpretive results, Mr. Cooksley was asked if he would reinterpret the specific shot point over the proposed drill hole at A-2 using his seismic data collected earlier. "Tight hole" conditions were imposed on the contacts and depth by ASARCO personnel, and hopefully the drillers. To our knowledge, neither J.W.C.,Jr. nor his people were on the site during drilling of A-2. Again, the results of his interpretation were not received prior to the termination of the hole at its present depth of 4082 on February 7.

Our own interpretation of the contacts is not clear from the rotary cuttings and the few fragmented pieces recovered during spot coring. Upon coring by a diamond drill rig of the intervals, it will be specific and, at that time, a followup memo will be submitted.

James D. Sell

James D. Sell

JDS:lad
Attachs.

Date	Drill Hole Depth	Site	Interpreted Contacts	By
2/7/72	4082	Drill	0 - 1330 Td * 1330 - 2020 Tcw * 2020 - 3935 Tcw * 3935 - 4082 Tgz? Fe ss * (Note *: Interpreted from rotary cuttings - subject to some variation.)	RB Cummings
2/7/72	4082	Moe's Drillsite	0 - 1500 Td w/ Tcw 1500 - 3700 Tcw 3700 - 4550 Tgz?, homogeneous offset 4550 - 5200 Sediments?, highly reflective	JW Cooksley
2/15/72	4082	Drill Station	0 - ~~1500~~ ? Td w/ Tcw ~~1500~~ ? - 3660 Tcw 3660 ~~[illegible]~~ ~~[illegible]~~ Tgz? / Host rock. 4200 ~~[illegible]~~ reflective discontinuity. 4800 strong reflective discontinuity.	JW Cooksley

4080

Spot cores, with very poor results, were cut at

2059 - 2073 = Whitetail Conglomerate

3459 - 3540

3540 - 5550 = Whitetail Conglomerate (?) or Slide Block (?) or Weathered Intrusive (?)?

4081 - 4082 ~~[illegible]~~ = Intrusive & schist

The cores were not diagnostic and especially the poor fragments collected between 3540 - 3550. RB Cummings suggests it is Whitetail Conglomerate but he adds that cuttings from 3459 - 3540 suggests that a slide block of schist - intrusive material may exists and lay on weathered intrusive.

J. W. COOKSLEY, JR.
Geophysicist - Geological Engineer
APPLIED EARTH SCIENCES
BOX 2749 TUCSON, ARIZONA 85702
AREA CODE 602 - 622-8668

22 February 1972

American Smelting & Refining Company
Southwestern Exploration Division
P.O. Box 5747
Tucson, Arizona 85703

Attention: Jim Sell

Enclosed herewith are the copies of Plates 1 and 2 with the added information you requested.

Sincerely,

J. W. Cooksley, Jr.
Geophysicist

JWC/ksk

9/85

COMPARISON OF SEISMIC EXPLORATION RESULTS WITH DATA ON THREE DEEP DRILL HOLES, SUPERIOR EAST PROJECT NEAR SUPERIOR, ARIZONA

Conducted for

AMERICAN SMELTING AND REFINING COMPANY

Prepared by

J. W. Cooksley, Jr.

J. W. Cooksley, Jr.
Geophysicist

February, 1972

Copy No. _____

To Q. S.O.C.

Date 2-15-72 Time 4:05 PM

WHILE YOU WERE OUT

Mr. Cookseley

of

Phone 622-8668

- [x] TELEPHONED
- [ ] CALLED TO SEE YOU
- [ ] WANTS TO SEE YOU
- [x] PLEASE CALL HIM
- [ ] WILL CALL AGAIN
- [ ] RUSH

Message: On record at Shell Site

3 1/2" top of first rock

4 7/8" another discount

4 5/8" even larger discount.

H. Maples Operator

YERG INC. BELLEVILLE, N. J. FORM 3

2/7/72 on pt 1000 ft S of A-2

Jim Cashelly

2/7/72
Jim Cashelly

A-2 Verbal & log Thoughts.

0-1330 Td
1330-2020 Tev
2020-3935? Tw

base
Td = 9000 fps @ 0.4 sec = 1800 ft
slight mess in signal at base of Td
suggests some Tev.

base
Tw = 12000 fps @ 0.62 sec = 3720 ft base
@ 0.5 = 3000 ft something in Tw
siltstone? or something volcanic
with possibly bones below.
Possible ± 200 ft thick.

Dunsile
Premier = 12500 fps to 13000 fps @ 0.7 sec to 0.8
= 4550 ft to 5200 ft to top of much
layer material ? sediments
under rather homogeneous
material of ? granite? or
more probable a thrust plate ???

Ma

0-1330 Td
1330-2020 Tev
2020-3935 Tw

J. W. COOKSLEY, JR.
Geophysicist - Geological Engineer

APPLIED EARTH SCIENCES
BOX 2749 TUCSON, ARIZONA 85702
AREA CODE 602 - 622-8668

6 January 1972

American Smelting and Refining Company
Southwestern Exploration Division
P. O. Box 5747
Tucson, Arizona 85703

Attention: James D. Sell

Reference: Billing for Phase II of downhole and reflection seismic investigation of subsurface geology at the Superior East Project in Gila and Pinal Counties, Arizona.

LINE C - Rework

Computer Service @ cost		$ 360.00
Geophysicist @ $25.00/hour	8 hours	200.00
Assistant Geophysicist @ $12.50/hour	8 hours	100.00

A-4 DOWNHOLE - Field

Geophysicist @ $25.00/hour	6 hours	150.00
Seismic Operator @ $12.50/hour	16 hours	200.00
Field Assistant @ $8.00/hour	16 hours	128.00
Downhole System @ $400.00/day	1 day	400.00
Drill @ $50.00/day	1 day	50.00
Vehicle @ $15.00/day, 15¢/mile		
2 vehicles for 2 days, 300 miles		150.00
Per Diem - 3 man crew - Motel	$30.00	
Meals	70.00	100.00

VELOCITY STUDY OF SUPERIOR EAST PROJECT

Geophysicist @ $25.00/hour	32 hours	800.00
Assistant Geophysicist @ $12.50/hour	8 hours	100.00
Reproductions, typing		55.00
	TOTAL INVOICE	$2,793.00

OK for Payment
Superior East MA-0010-04
James D. Sell

TABLE OF CONTENTS

INTRODUCTION

The preliminary report on the seismic investigation on the Margaret Claim-Group ("Reflection Seismic Survey Conducted on the Margaret Claims Located About Four Miles Northeast of Superior, Arizona"), dated June 1970, had used the data derived from drill hole DCA-2, which is near the eastern edge of the dacite plateau (in Sec. 11, T. 1 S., R. 13 E.), as a basis for computing depths to various geologic units. Since that time, two more holes (M-1 and A-4) have been drilled within the immediate area of interest, and data from these holes have necessitated a revision of the earlier depth estimates. In addition, a north-south seismic traverse, Seismic Line I-1, has been run northward from drill hole I-1. This traverse provided seismic data that could be checked against the drilling data obtained from that hole.

The location map on the next page shows the seismic profile lines in relation to the drill holes.

The more recent information has revealed that the originally calculated depths to the top of the host rock units were erroneous because the unusually high seismic velocity in the Whitetail Conglomerate in this area had been underestimated. The original computations had been based on an average velocity of 6,000 fps between the surface of the ground and the top of the host rock units, as derived from correlation of Seismic Line A with drill hole DCA-2 (both to the northeast of the location map area). At DCA-2, however, only 225 ft. of Whitetail Conglomerate is present, of a total post-mineral section of 1525 ft.

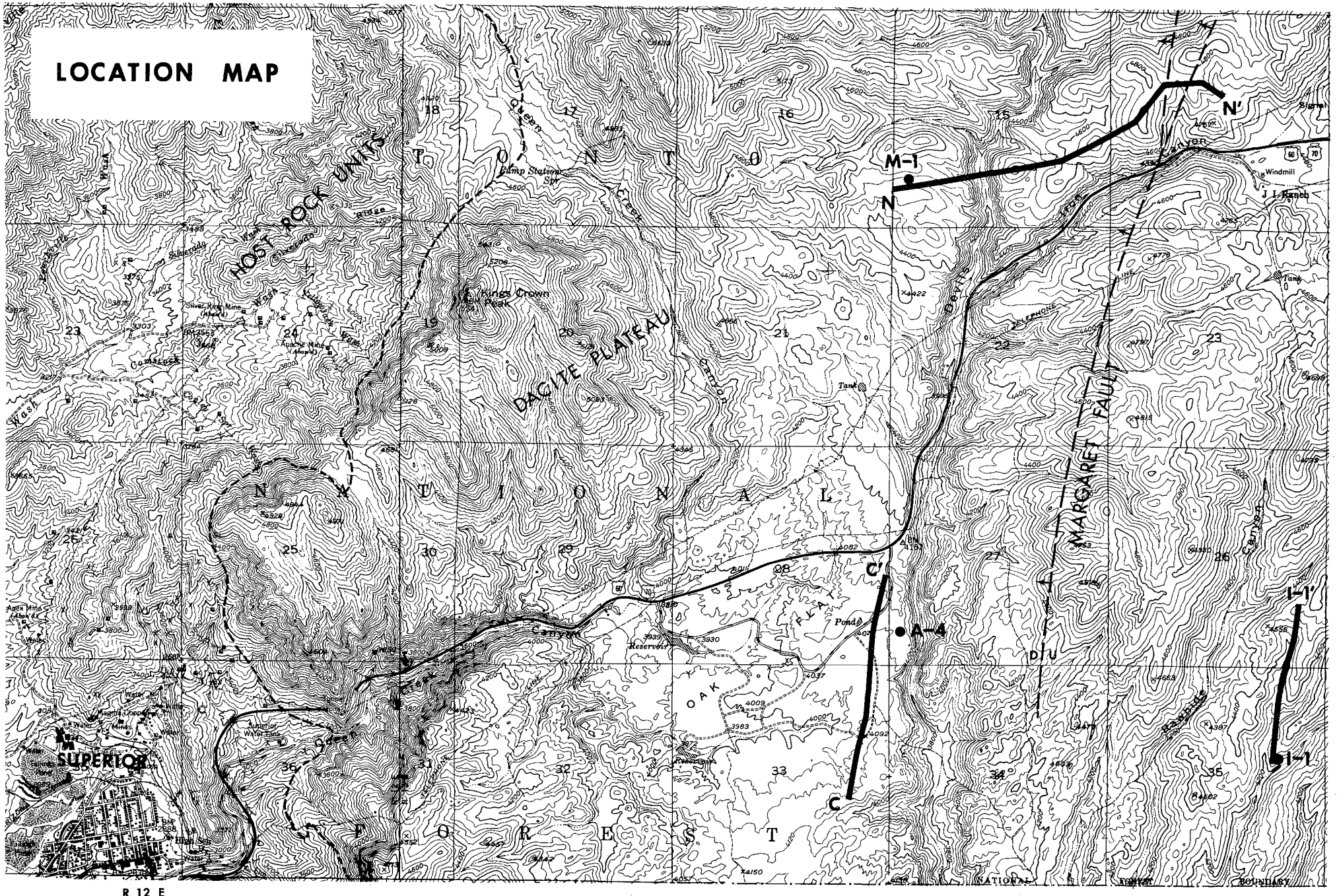
Because subsequent drilling operations proved that the use of the 6,000 fps average velocity to host rock units was too low, a study was conducted to assess the effectiveness of the various techniques of seismic computation and signal enhancement, and a program was developed for preparation, processing, and computing the seismic data. This program is subject to continuous scrutiny and development, but it has evolved into a usable tool for mining geological investigations to find the depth to and study the nature of host rock units that are covered by thick sections of barren post-mineral rock. Included in this program are velocity profiles, frequency analysis, digital filtering, and static and dynamic corrections. The program is built mainly around the velocity profile. The velocity profile depicts the seismic velocity as determined by a digital correlation technique at any time from 0 to 1.0 (or more) seconds on the seismic record. The time is corrected to datum. This phase of the program is used to

(1) effect the best dynamic correction for the seismic data,
(2) pick seismic reflections and detect "multiple reflections" and "diffractions,"
(3) measure seismic velocity without the use of a drill hole.

Geologic Background

In the area of the investigation, the older, host rock units are covered by conglomerate and volcanic rock (the "dacite") of Tertiary age. The total post-mineral section is more than 6,000 ft. thick at drill hole A-4, which is near the center of the dacite plateau. About 2 mi. north of A-4, drill hole M-1 encountered 4,898 ft. of the post-mineral section. To the east, particularly east of the Margaret fault, the post-mineral section is much thinner, e.g., 2,939 ft. at drill hole I-1 and 1,525 ft. at drill hole DCA-2.

LOCATION MAP



The normal post-mineral sequence encountered in the drill holes completed to date consists of dacitic tuff (the dacite) and an underlying (locally absent) volcanic section of andesitic flow and pyroclastic rock. These volcanic rocks commonly attain a combined thickness of 2,000 ft. They overlie the Whitetail Conglomerate, which has a thickness of about 4,000 ft. at drill hole A-4 but pinches out altogether or to thicknesses of only a few hundred feet in a distance of only 3 mi. to the west and east. The thickness of the Whitetail appears to be influenced strongly by block faulting that occurred during the period of deposition.

At the western edge of the dacite plateau, the host rock units consist of Paleozoic sedimentary formations and Precambrian sedimentary and volcanic strata that have been intruded by diabase sills. In the eastern portion of the dacite plateau the pre-mineral assemblage consists mainly of Pinal Schist and Schultze Granite.

Seismic reflections originate at the tops of the rock units of both the post- and pre-mineral assemblages. The best reflections are usually associated with the top of the Whitetail Conglomerate, the top of the host rock section, and some of the units within the host rock assemblage.

DEFINITIONS

In the following discussions, the following definitions apply.

average velocity. The average velocity of a seismic wave from a point in the subsurface to the ground surface:

$$V_{ave} = \text{Depth/Time.}$$

interval velocity. The average velocity of a seismic wave within a geologic unit(s):

$$V_{int} = \text{Thickness/(Time at Bottom} - \text{Time at Top).}$$

downhole velocities (both average and interval). Velocities measured by lowering a seismic sensor down a drill hole and measuring the travel times of seismic waves originating at the surface near the collar of the drill hole.

velocity profile. A velocity profile at a shot point is a measure of apparent average velocity at a given record time. It is based on the standard formula

$$T^2 = T_{vert}^2 + X^2/V_{ave}^2$$

where

T is two-way reflection travel time
T_{vert} is two-way vertical reflection time
X is the distance from shot point to sensor
V_{ave} is average velocity.

In practice, correlation across traces is performed for each T_{vert} at 0.020-sec increments at trial velocities from 1,000 to 19,000 fps (or similar range of velocities) in 100-fps increments. The X's are known, and each trial velocity provides the appropriate T about which a small window of data is used in the correlation analysis. A measure of the correlation of the traces for each trial velocity and T_{vert} is displayed graphically. The three maximum peaks on each of these curves are indicated on a separate computer print, and their values are listed. Theoretically the highest peak values correspond to the strongest signal energy and are indicative of possible reflections and the corresponding average velocity to the reflection. These velocity profiles are interpreted to provide a measure of average velocity at various reflection times and provide the dynamic corrections for the traces. (Courtesy of D. Fink, General Atronic Corporation, Philadelphia, Pa.)

SEISMIC VELOCITY MEASUREMENTS

Three methods have been used to determine the average velocity from the ground surface to the top of a geologic unit represented by a seismic discontinuity. These methods are as follows:

1. Downhole surveys conducted on drill holes. An energy source is applied at the surface near the collar of the hole, and the seismic waves are recorded with a sensor or sensors lowered down the hole. A one-way travel time is recorded seismically, and the depth is measured on the sensor cable.

   Thus: $$V_{ave} = \frac{\text{Depth}}{\text{Time}} .$$

   (This is the only method of the three discussed in which the depth of a given seismic event can be identified positively.)

2. Correlation of seismic events with drill hole data and computation of velocities using the depth (distance) data from the drill hole and the time data from the seismic records. In this case the time of an event recorded on the seismic record is divided by 2 because it represents a two-way (down and up) travel time.

   Thus: $$V_{ave} = \frac{\text{Depth}}{\text{Time}/2} .$$

3. Interpretation of velocity profiles.

Velocity from Downhole Survey

A downhole seismic survey was done on drill hole A-4 to a depth of 4,490 ft. (the length of the cable available). Appendix A shows field layout and seismic traces for this survey. Two sensors were used. Although only one was needed to furnish average velocity to the surface, a second sensor spaced 150 ft. up the hole was used to compute the interval velocity over the 150-ft. increment. The downhole survey on hole A-4 yielded the following:

(1) A positive identification of reflections originating in the upper 60% of the Whitetail section.
(2) Three average velocity measurements between depths ranging from about 3,500 ft. to about 4,500 ft. and the ground surface.
(3) Interval velocities over two 150-ft. sections of the drill hole between depths of 3,900 ft. and 4,500 ft.

Table I summarizes the average velocities and the interval velocities measured.

Table I. Average and Interval Velocities from Downhole Survey (Drill Hole A-4).

Measured depth, ft.	Measured time, sec	Calculated V_{ave}, fps	Measured T_{int}, sec	Calculated V_{int}, fps (= 150/T)
3,640	0.284	12,800	–	–
3,990	0.310	12,900	0.0085	17,600
4,490	0.343	13,100	0.0085	17,600

As will be discussed under COMPARISON OF SEISMIC DISCONTINUITIES WITH DRILL HOLE GEOLOGY (pp. 9 to 12) and shown in Table II, it was possible to pick a seismic reflection event at 0.910 sec from the raw seismic field record obtained during the shooting of the downhole data. This event, interpreted to be the top of the host rock units, made it possible to compute an approximate average velocity to the top of the host rock assemblage and an interval velocity for the Whitetail Conglomerate, assuming that the depth to the top of the host rock assemblage at drill hole A-4 is approximately 6,300 ft. These velocities are shown in Table II as 13,850 fps and 16,340 fps, respectively.

Velocity by Correlation of Seismic Events with Drill Hole Data

The first step in computing seismic velocity by correlating seismic events with drill hole data is to pick the events on the seismic record that represent geologic contacts or other features that are identifiable in the drill hole. This correlation is shown on the records in Appendix B. The geologic interpretation of these events is labeled, and the depths at which the features were encountered in the drill hole are noted. Next, the two-way travel time of the seismic waves is recorded (from the source at the ground surface to the discontinuity plus from the discontinuity back up to the sensors at the ground surface) after normal static and dynamic corrections have been made. The datum-corrected times are further corrected to the time which represents the drill hole collar elevation. At the drill holes discussed in this report, the time corrections to collar elevations are –0.100 sec for M-1, –0.070 sec for I-1, and –0.100 sec for A-4.

To compute the average velocity to the correlated feature,

$$V_{ave} = \frac{D}{T/2}$$

where D = depth
T = two-way time.

To compute the interval velocity between two correlated features,

$$V_{int} = \frac{D_2 - D_1}{(T_2 - T_1)/2}$$

where D_1 = depth to upper unit
D_2 = depth to lower unit
T_1 = two-way time to upper unit
T_2 = two-way time to lower unit

Table II presents the velocity data acquired by the correlation method at drill holes M-1, I-1, and A-4, in addition to the downhole velocity data from drill hole A-4.

Table II. Seismic Velocity Measurement from Correlation of Seismic and Drill Hole Data.

Geologic unit	Depth, ft. To Top	Depth, ft. To Base	Time, sec* To Top	Time, sec* To Base	V_{ave}, fps To Top	V_{ave}, fps To Base	V_{int}, fps
Line N – Drill Hole M-1							
Dacite	0	1,890	0	.480	–	7,900	7,900
Older volcanics	1,890	2,428	.480	.580	7,900	8,400	10,760
Upper Whitetail	2,428	3,108	.580	.720	8,400	8,600	9,700
Lower Whitetail	3,108	4,898	.720	.960	8,600	10,200	14,900
Total Whitetail	2,428	4,898	.580	.960	8,400	10,200	13,000
Line I-1 – Drill Hole I-1							
Dacite	0	1,105	0	.360	–	6,140	6,140
Whitetail	1,105	2,939	.360	.580	6,140	10,130	16,670
Line C – Drill Hole A-4							
Dacite	0	1,975	0	.370	–	10,680	10,680
Older volcanics	1,975	2,133	.370	.400	10,680	10,660	10,500
Whitetail	2,133	6,300 5,680**	.400	.800	10,660	15,750 14,200**	20,840 17,740**
Downhole Spread A-4 – Drill Hole A-4							
Dacite and older volcanics***	0	2,133	0	.400	–	10,660	10,660
Whitetail	2,133	6,300	.400	.910	10,660	13,850	16,340

*All times given are converted from original datum to the collar of the drill hole. Corrections are as follows: –0.100 sec for M-1, –0.070 sec for I-1, –0.100 sec for A-4.

**The upper row of figures for V_{ave} to the top of the host rock assemblage and the V_{int} of the Whitetail Conglomerate appear to be too high. Downhole shooting indicates that the host rock assemblage is 750 to 800 ft. deeper at drill hole A-4 than at shot point 8 on Line C. (See VELOCITY FROM DOWNHOLE SURVEY, previous section.) If the top of the host rock assemblage is at a depth of 5,680 ft. instead of 6,300 ft., then these revised figures apply.

***Data concerning V_{int} for the dacite and the older volcanics individually are omitted because the contact between these units is not definable on the field seismic record. Further processing of the seismic data would be required to make this reading possible.

Velocity from Interpretation of Velocity Profiles

Velocity profiles from seismic shot points near drill holes M-1, I-1, and A-4 are given in Appendix C. Several parameters, both geophysical and geological, are considered in the interpretation of these profiles. Interpreted curves representing the average velocity have been drawn on the velocity profiles. These curves have not been adjusted to correlate with either the drill hole information or each other. Several points and some sections of curves occupy positions away from the interpreted curve; possible causes for the deviations include diffractions, reflected refractions, multiple reflections, and low velocity zones in the rock.

Depths to discontinuities are computed by dividing the time of the event on the seismic record by 2 and multiplying by the average velocity indicated on the velocity profile at the time of the event:

$$D = (T/2)\, V_{ave}.$$

Using the velocity profile data, interval velocities are computed with the same formulas as used for the correlations with drill holes; however, the depth data are computed using the average velocity from the velocity profile and the two-way travel time of the reflected event shown on the seismic record instead of from the depths obtained from drill hole data.

Table III presents depth and interval computations at the three drill holes.

Table III. Depth and Seismic Interval Velocity Computations from Interpretation of Velocity Profiles.

Geologic unit	Time, sec*		V_{ave}, fps		Depth, ft.		V_{int}, fps
	To top	To base	To top	To base	To top	To base	
Line N – Drill Hole M-1							
Upper Whitetail	0.580		7,400 at 0.680 sec		2,140		10,570
Lower Whitetail	0.720		8,000 at 0.820 sec		2,880		16,420
Total Whitetail		0.960		10,100 at 1.060 sec		4,850	14,260
Line I-1 – Drill Hole I-1							
Whitetail	0.360	0.580	7,000 at 0.430 sec	10,600 at 0.650 sec to 11,000	1,260	3,070	16,450
Line C – Drill Hole A-4							
Whitetail	0.400	0.800	10,500 at 0.500 sec	14,200 at 0.900 sec	2,100	5,680	17,900

*All times given are converted from original datum (see times cited in V_{ave} column) to the collar of the drill hole. Corrections are as follows: −0.100 sec for M-1, −0.070 sec for I-1, −0.100 sec for A-4.

COMPARISON OF SEISMIC DISCONTINUITIES WITH DRILL HOLE GEOLOGY

Drill Hole M-1A

In summer, 1970, the M-1 drill site was chosen, based in large part upon the findings of the seismic work conducted during the preceding winter. Using the 6,000 fps average velocity derived from the measurements taken along Line A and from drill hole DCA-2, it was computed that the top of the host rock units along Seismic Line N in the vicinity of drill hole M-1 would be found at a depth of 2,400 ft. M-1 actually entered the host rock units at a depth of 4,898 ft., twice the depth computed from the seismic work. Using the times of seismic events on Seismic Line N, and comparing these times with the depths of geologic units encountered in the nearby drill hole M-1, the average velocity from ground surface to the top of the host rock units was recomputed to be more than 10,000 fps. In addition, the interval velocity for the total Whitetail Conglomerate section was computed to be 13,000 fps.

The cores from drill hole M-1 show the Whitetail Conglomerate to consist of two main rock types. The upper section, a well-bedded siltstone, probably possesses less velocity than the lower section, a poorly bedded to nonbedded conglomerate comprising mainly gravel- to cobble-size fragments of Pinal Schist bound in a matrix that is dense, sandy, and well consolidated. The contact between these sections seems to be represented by a seismic event occurring at 0.720 sec on the traces closest to M-1. (See Plate 1, Appendix B.) Comparison of seismic measurements with the drill hole data shows interval velocities of 9,700 fps and 14,900 fps for the upper and lower sections of Whitetail Conglomerate, respectively. The rather substantial section (680 ft.) of the low-velocity upper unit strongly affects the average velocity and hence results in a somewhat large reflection time to the host rock units at drill hole M-1.

The seismic field data on Line N were reworked using the more advanced procedures of the computing program mentioned in the INTRODUCTION. Included in these procedures were detailed study of velocity and frequency, and the employment of digital filtering. The improvement in record quality led to a revision of the interpretation of the top of the host rock units on the seismic records from about 0.800 sec to 1.060 sec (Plate 1, Appendix B). Velocity profiles from Shot Points 1 and 2 on Line N indicate the average velocity to the top of the host rock units is about 10,100 fps. (See Plates 1 and 2 in Appendix C.) Using this velocity and the time reflection of 1.060 sec, minus 0.100 sec to correct from datum to ground surface, the depth to the host rock units is

$$(1.060 \text{ sec} - 0.100 \text{ sec})/2 \times 10{,}100 \text{ fps} = 4{,}850 \text{ ft.}$$

This compares well with the 4,898-ft. depth ascertained in drill hole M-1. Table IV summarizes the comparison of depth data (1) as originally computed, (2) as computed using the average velocity indicated by the velocity profile, and (3) as found in drill hole M-1.

Table IV. Depths to tops of upper Whitetail Conglomerate, lower Whitetail Conglomerate, and host rock units, as determined seismically (using average velocity = 6,000 fps and using average velocity from velocity profile), compared with data from drill hole M-1.

Geologic unit	Depth, ft. Seismic computations: From DCA-2 (V_{ave} = 6,000 fps)	Depth, ft. Seismic computations: From velocity profile	Depth, ft. Drill hole M-1
Top of upper Whitetail Conglomerate (0.580 sec)	1,740	2,140 (V_{ave} = 7,400 fps)	2,428
Top of lower Whitetail Conglomerate (0.720 sec)	2,220	2,880 (V_{ave} = 8,000 fps)	3,108±
Top of host-rock assemblage (0.960 sec)	2,880	4,850 (V_{ave} = 10,100 fps)	4,898

Drill Hole I-1 AOF-1 (Inspiration)

In the north-south seismic traverse running north from drill hole I-1, the travel times of the seismic discontinuities interpreted to be the tops of Whitetail Conglomerate and the host rock assemblage were ascertained from the seismic record section; using the velocity profile from the shot points closest to drill hole I-1, the average velocities to these discontinuities were interpreted. (See Plates 3 and 4, Appendix C.) Using average velocities of 7,000 fps at the top of the Whitetail Conglomerate and 10,600 fps at the top of premineral diabase (see Plate 2, Appendix B), the depths of the reflection events representing the tops of the units were computed and found to correlate well with the drill hole data. Table V summarizes the comparison.

Table V. Depths to tops of Whitetail Conglomerate and host rock units as determined seismically, compared with data from drill hole I-1.

Geologic unit	Depth, ft. Seismic computation from velocity profile	Depth, ft. Drill hole I-1
Top of Whitetail Conglomerate	1,260	1,105
Top of host rock assemblage	3,070	2,939

This good correlation of the seismic data with the drill hole data was achieved by using the *velocity profile* to estimate the average velocities that were used to compute the depths. No drill hole data were used to compute these depths.

Drill Hole A-4

A seismic reflection event interpreted to be the top of pre-mineral rock takes place at 0.900 sec in the part of Seismic Line C that is closest to drill hole A-4. (See Plate 3, Appendix B.) Using the original average velocity of 6,000 fps, and a datum to ground-corrected time of 0.800 sec, the initial estimate for the depth to the host rock units in this area was about 2,400 ft. Data from correlation at drill holes M-1 and I-1 indicated that this estimate was incorrect. The data underwent additional computing work to obtain a more detailed and comprehensive analysis. In the first phase of the upgrading program, velocity profiles were derived at three shot points, SP 1, SP 4, and SP 8. Shot Point 8 is closest to drill hole A-4 (about 1,000 ft. west of the drill site). The velocity profiles showed the average velocity in the 0.900-sec portion of the record to be about 14,200 fps. (See Plates 5 and 6 showing data from SP 8 in Appendix C.)

A 14,200-fps velocity seemed to be too high in view of the 10,200 and 10,130 fps average velocities to the top of host rock units computed at drill holes M-1 and I-1. Favoring the velocities computed from the correlations performed at M-1 and I-1, an average velocity of 11,000 fps was used to compute the depth to the top of the host rock units at Line C and to estimate the depth to the host rock units at drill hole A-4. The 11,000-fps average velocity yields a depth of 4,400 ft. The 14,200-fps average velocity from the velocity analysis yields a depth of 5,680 ft. In retrospect, it is obvious that the 14,200 fps from the velocity profile was the more accurate and that velocities from velocity profiles should be used in favor of extrapolation of average velocities from distant drill holes.

At the completion of drilling on A-4, a downhole seismic survey was conducted to a depth of 4,490 ft., the depth permitted by the amount of cable available. At 4,490 ft., the average velocity to the surface is about 13,100 fps and the interval velocity in the section of Whitetail Conglomerate between 4,340 and 4,490 ft. is about 17,600 fps. These data tend to substantiate velocity profile data that show an average velocity of 14,200 fps at a depth of 6,000 ft. and a 17,500-fps velocity through the total Whitetail section. (See Seismic Recordings, Appendix A.)

Table VI summarizes the comparison of depths to the host rock units at drill hole A-4 and Seismic Line C.

Table VI. Comparison of depths to top of host rock units as determined seismically, compared with data from drill hole A-4.

	Depth, ft.		
	Seismic computations		Drill hole A-4
Geologic unit	From M-1 and I-1 (V_{ave} = 11,000 fps)	From vel. profile (V_{ave} = 14,200 fps)	
Top of host rock assemblage	4,400	5,680	6,300 (?)

An interesting observation was made on the records shot in the downhole velocity measurements. A regular 1,150-ft.-long seismic spread was placed in a north-south direction and centered over drill hole A-4. This spread was recorded simultaneously with the downhole

data. The interesting part of this procedure is that a two-way travel time of about 0.910 sec to the top of the host rock assemblage was recorded. The depth to the host rock assemblage using the average velocity of 14,200 fps indicated on the velocity profile at SP 8 is

$$(0.910 \text{ sec} \times 14{,}200 \text{ fps})/2 = 6{,}461 \text{ ft.}$$

This depth compares well with the approximate depth of 6,300 ft. given to this office. There is a significant increase in two-way travel time to host rock units between Line C where the time was 0.800 sec and drill hole A-4 (about 1,000 ft. east of Line C) where the time was about 0.910 sec. This indicates that the top of the host rock assemblage is

$$[(0.910 - 0.800) \times 14{,}200 \text{ fps}]/2 = 781 \text{ ft.}$$

higher at Line C than at drill hole A-4.

CONCLUSIONS

In the period since January, 1970, when the first seismic exploration was performed on the dacite plateau between Superior and Miami, Arizona, much progress has been made in

measuring depths of rock units,
delineating faults,
and predicting the general rock type in the host rock assemblage.

This report is directed entirely to the first item and, more particularly, to measuring the depths to

the top of the Whitetail Conglomerate
and the top of the host rock assemblage.

To determine the effectiveness of the seismic measurements, three selected seismic sections were compared with the findings of drill holes located in areas where the top of the host rock assemblage is rather deep–ranging from 2,939 ft. to about 6,300 ft. It was established that the seismic discontinuities representing the tops of the Whitetail Conglomerate and the host rock assemblage can be identified throughout most of the seismic record sections. Gaps in coverage are present where strong diffraction events–usually from faults–override and interfere with the response from the discontinuities in question. But the discontinuities on the seismic record sections are shown in terms of the travel time for seismic energy to go from the explosion source near the ground surface down to the discontinuity and then back up to the seismic detectors at the ground surface. The next problem is to convert the travel times of the seismic waves into terms of depth.

To convert the events shown in terms of time on the seismic record sections into discontinuities shown in terms of depth on a seismic-geologic model, the average velocity of the seismic waves between the ground surface and the discontinuity must be known. The following approaches to determine this average velocity have been used in this study.

1. Downhole survey in which a direct measurement of seismic velocity is accomplished by placing seismic sensors down a drill hole and placing the seismic source at the surface near the collar of the drill hole.

2. Correlation of seismic events with rock units identified from the drill hole data. The velocity is computed from the depth indicated from the drill hole and the time read on the seismic record section.

3. Interpretation of seismic velocity profiles.

All three methods yielded essentially the same average velocities for the respective portions of the seismic traverses being investigated. We conclude that the most definitive data are those derived from the downhole survey because such data yield

positive identification of reflections,
a direct measurement of average velocity,
and a direct measurement of interval velocity when two phones are used, one at each end of the interval under study.

Interpretation of seismic velocity profiles is the only available method to determine velocity when no drilling data are available. The findings of this report show that accurate measurements of average velocity can be obtained with the careful interpretation of the velocity profiles. The reader is referred to Tables IV, V, and VI for comparison of depths to the discontinuities computed from the velocity profiles versus the depths at which these same discontinuities were encountered in drill holes. It should be noted that in comparing Line C with drill hole A-4, the discontinuities on Line C are about 1,000 ft. west of the drill hole.

Appendix A. VELOCITY FROM DOWNHOLE SURVEY (DRILL HOLE A-4)

Seismic Recordings

Vertical scale is the time of the seismic recording (beginning at time 0 for the shot). Horizontal scale represents the position of the reflection points in the subsurface.

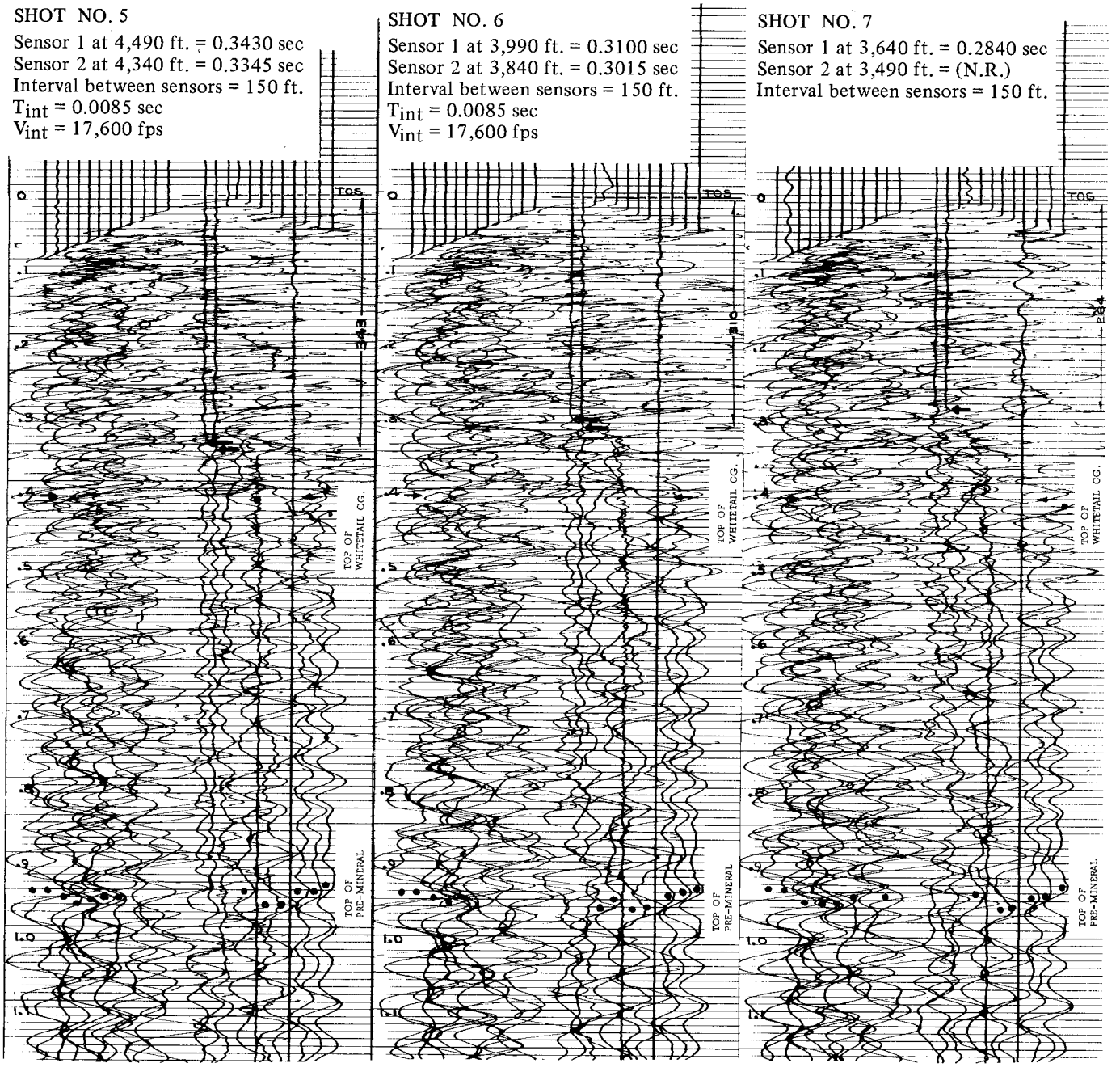
COLLAR OF HOLE at Sta. 550 ft.
Total depth of hole = 6,900± ft.

SHOT POINT at Sta. 400 ft.
Depth of S.P. = 8 ft.
Charge size = sticks of 60%

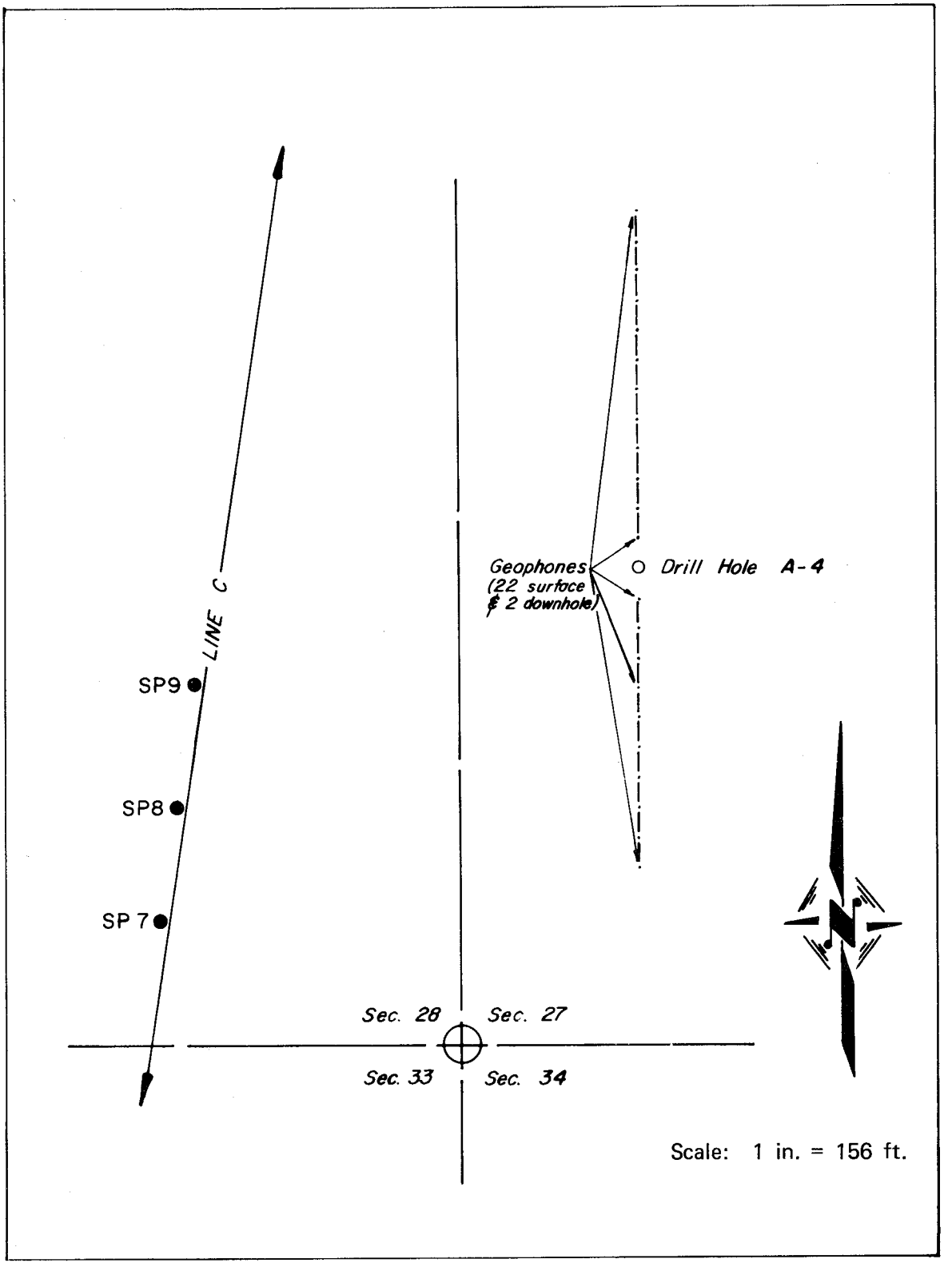
SHOT NO. 5
Sensor 1 at 4,490 ft. = 0.3430 sec
Sensor 2 at 4,340 ft. = 0.3345 sec
Interval between sensors = 150 ft.
T_{int} = 0.0085 sec
V_{int} = 17,600 fps

SHOT NO. 6
Sensor 1 at 3,990 ft. = 0.3100 sec
Sensor 2 at 3,840 ft. = 0.3015 sec
Interval between sensors = 150 ft.
T_{int} = 0.0085 sec
V_{int} = 17,600 fps

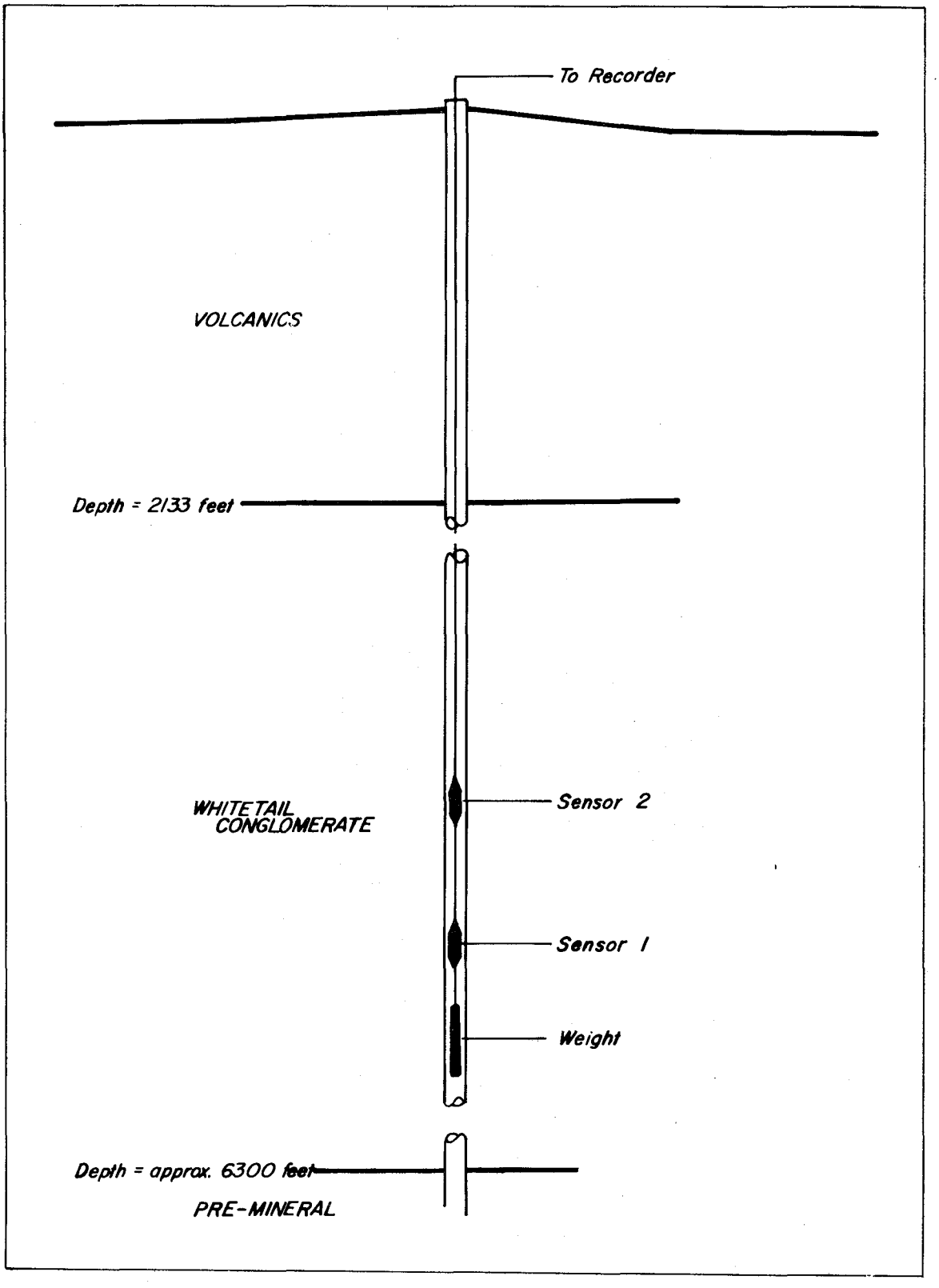
SHOT NO. 7
Sensor 1 at 3,640 ft. = 0.2840 sec
Sensor 2 at 3,490 ft. = (N.R.)
Interval between sensors = 150 ft.



Map


LINE C
SP9
SP8
SP 7
Geophones
(22 surface
& 2 downhole)
Drill Hole A-4
Sec. 28
Sec. 27
Sec. 33
Sec. 34
Scale: 1 in. = 156 ft.

Drill Hole Setup



Appendix B. VELOCITY BY CORRELATION OF SEISMIC EVENTS WITH DRILL HOLE DATA

Final seismic trace playouts that have been corrected for statics (topography) and normal moveout (time difference due to difference in length of ray path from shot point to reflection point and back to phone).

Vertical scale is the time of the seismic recording (beginning at time 0 for the shot). Horizontal scale represents the positions of the reflection points in the subsurface.

Playouts are color coded as follows: Dacite (green), older volcanics (orange), Whitetail Conglomerate (golden brown), host rock units (blue).

Plate 1 – Seismic Line N, Drill Hole M-1

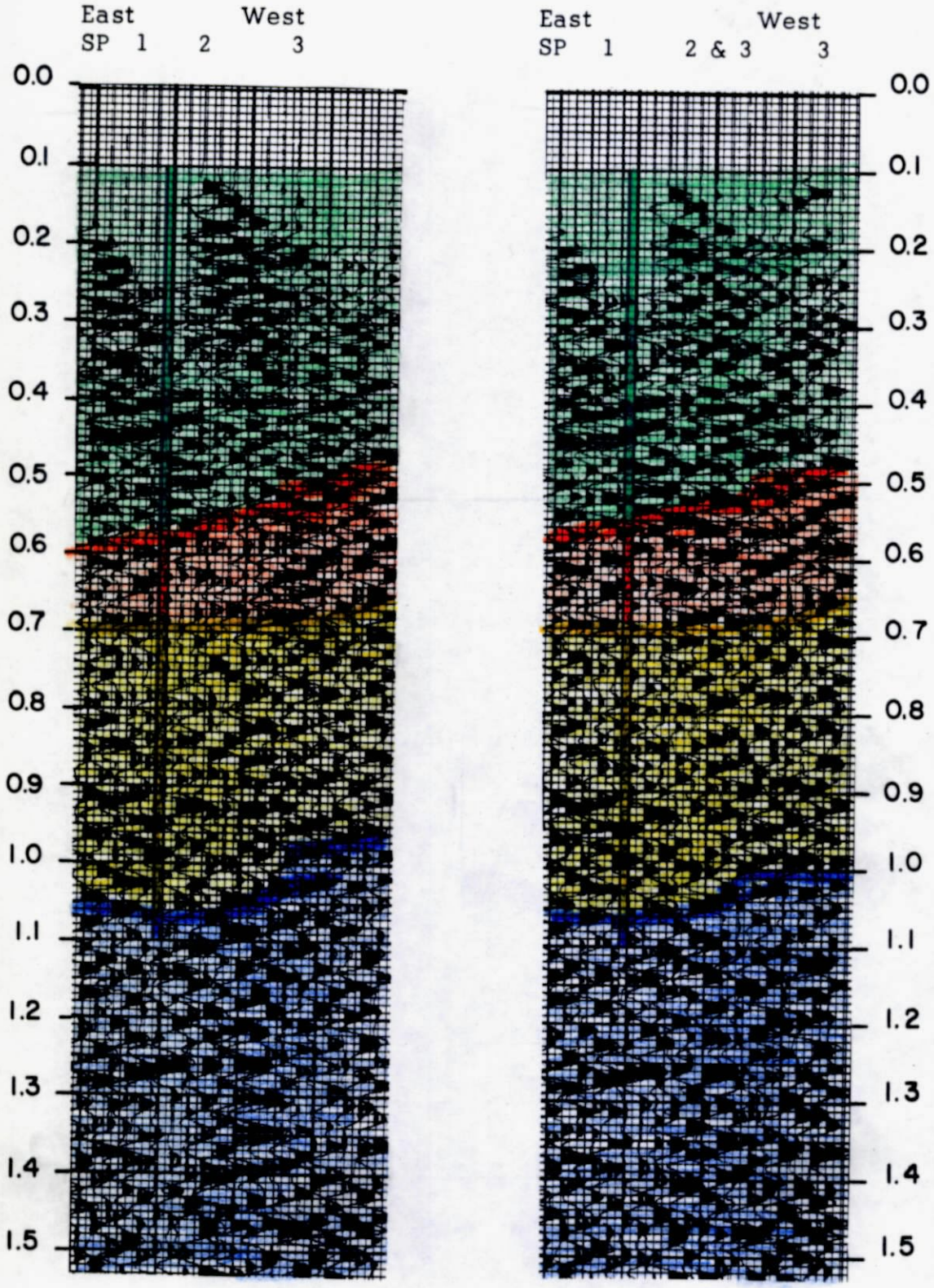


Plate 2 – Seismic Line I-1, Drill Hole I-1

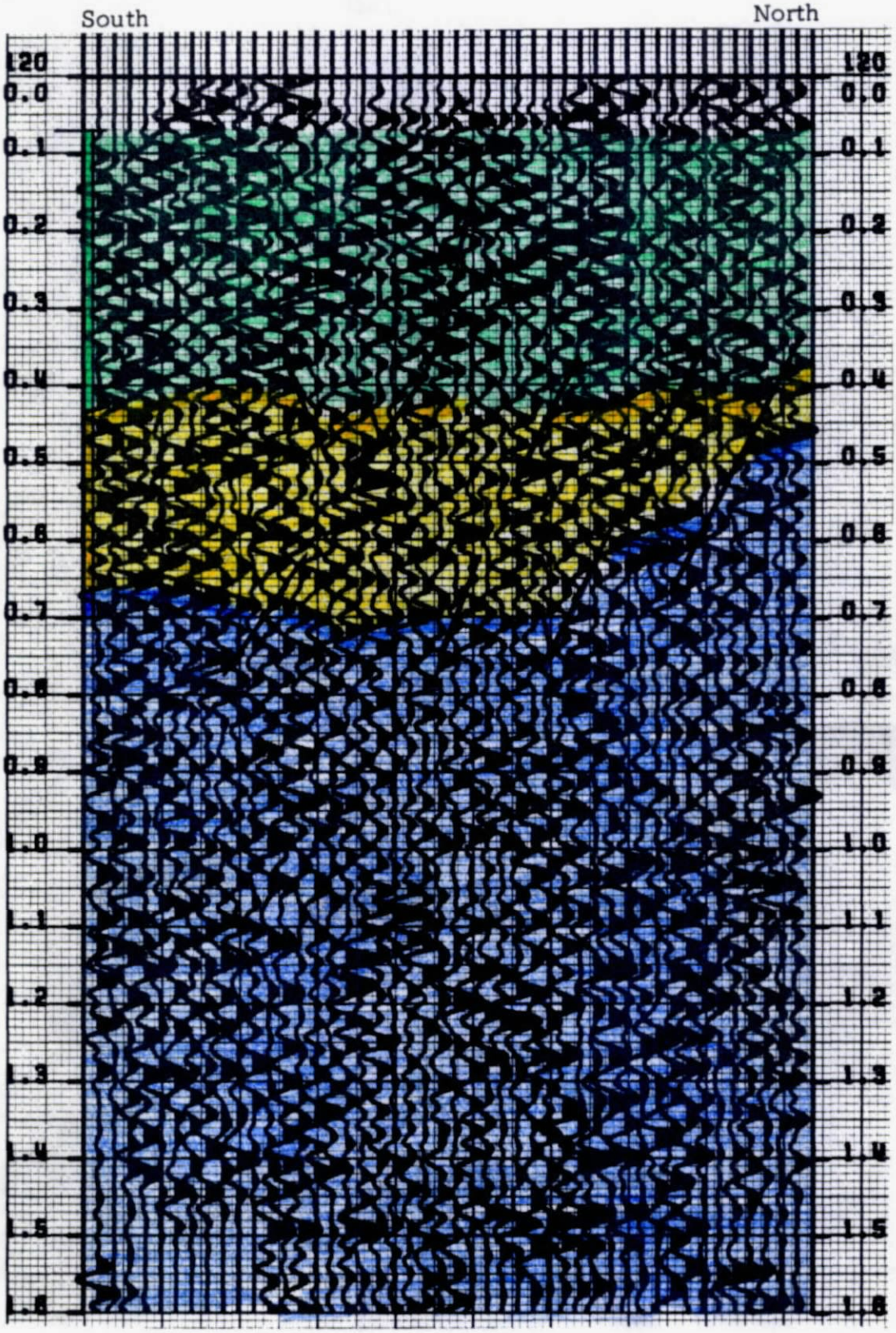
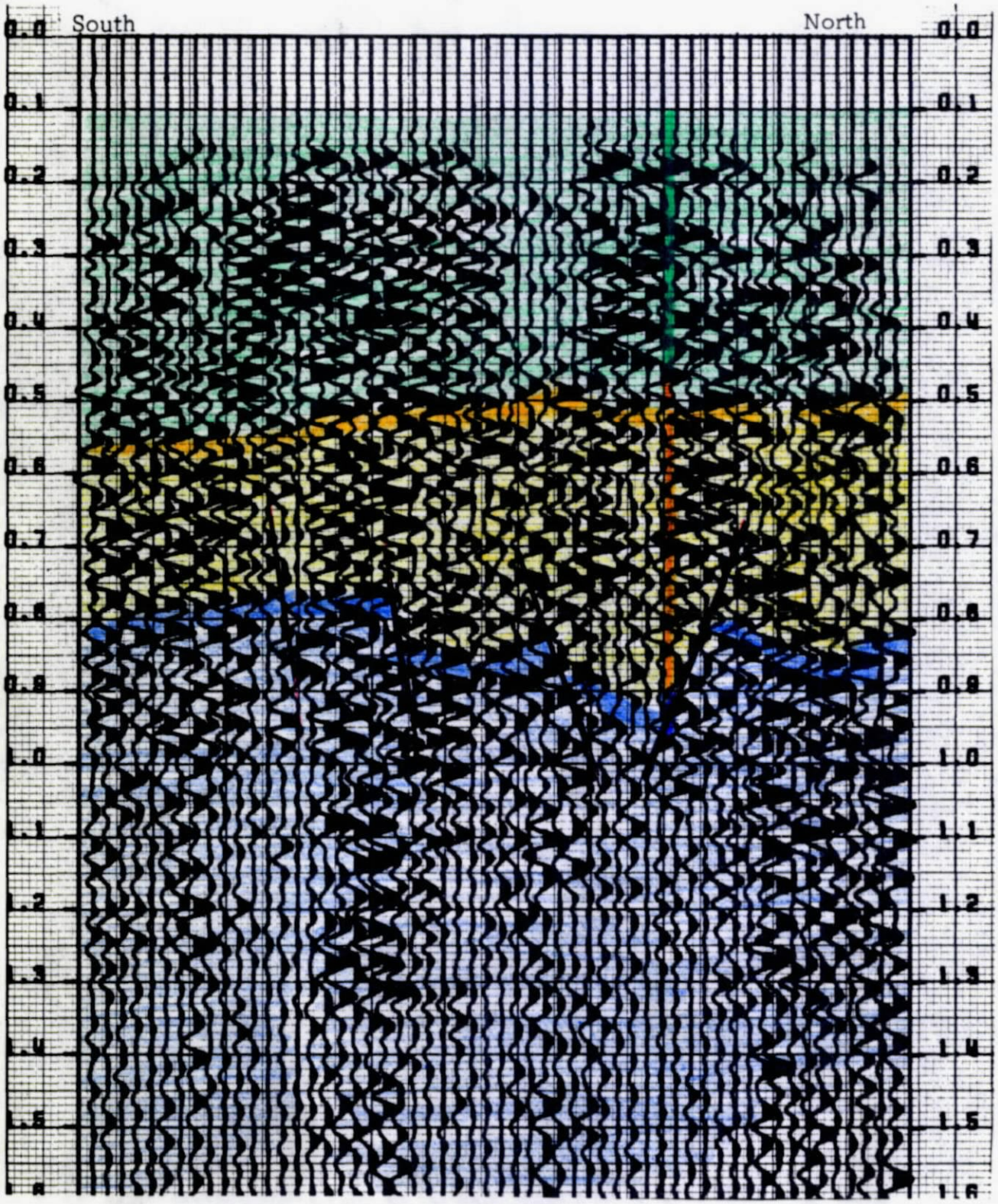


Plate 3 – Seismic Line C, Drill Hole A-4

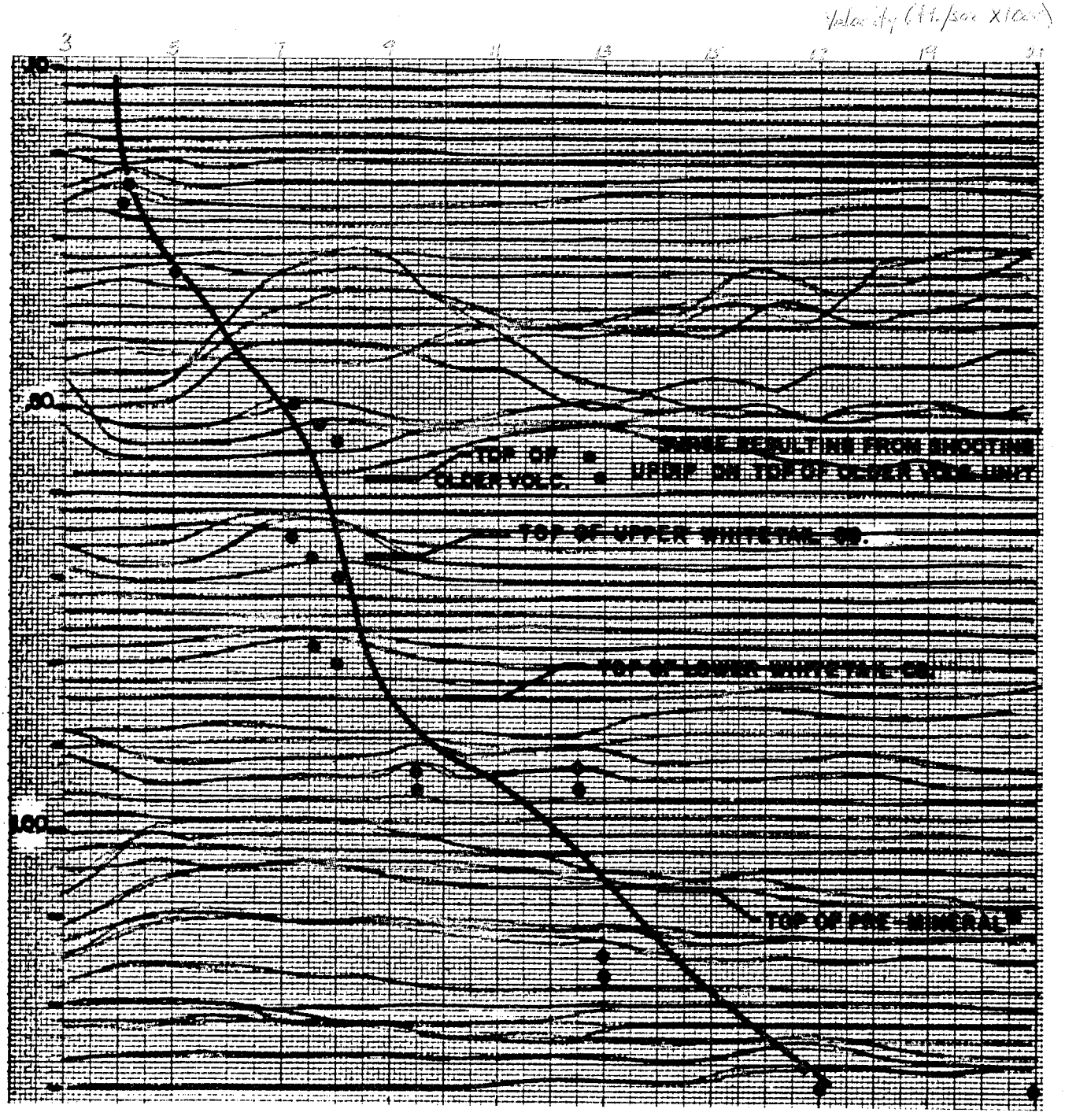


Appendix C. DERIVATION OF AVERAGE VELOCITY FROM INTERPRETATION OF VELOCITY PROFILES

The attached profiles are derived from the raw trace playouts of the original seismic records (which have corrections for topography incorporated).

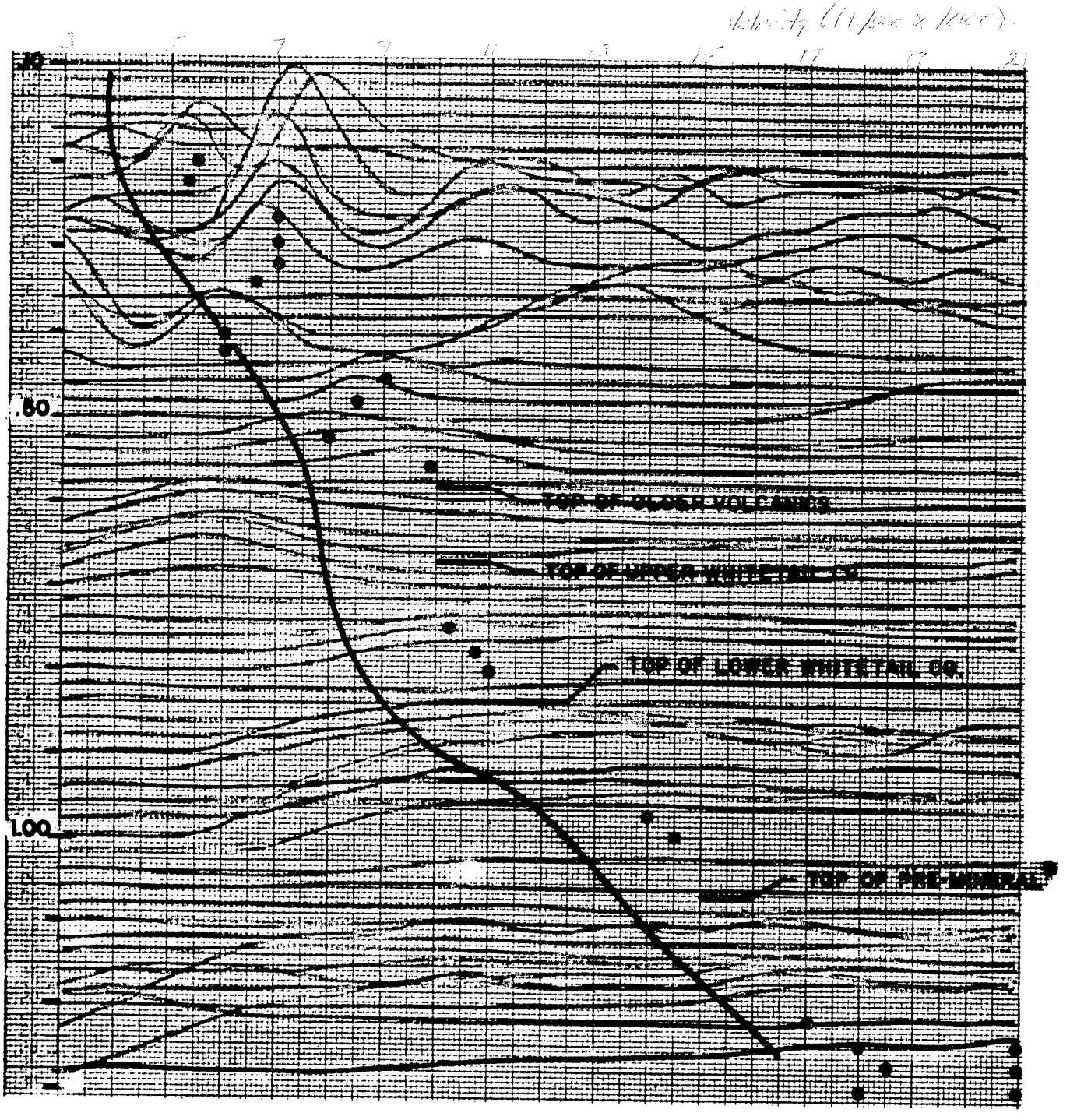
The vertical scale is the time along the seismic recording, beginning 0.100 sec after the shot. The horizontal scale is the velocity of the seismic wave, in thousands of feet per second. The configuration and amplitude of the horizontally trending curves are a measure of the correlation of the traces, which denotes a velocity. Heavy black dots have been added to show significant highs that suggest average velocity. Heavy black curve is the velocity function interpreted from the average velocity points.

Plate 1 — Line N, Velocity Profile Shot Point 1



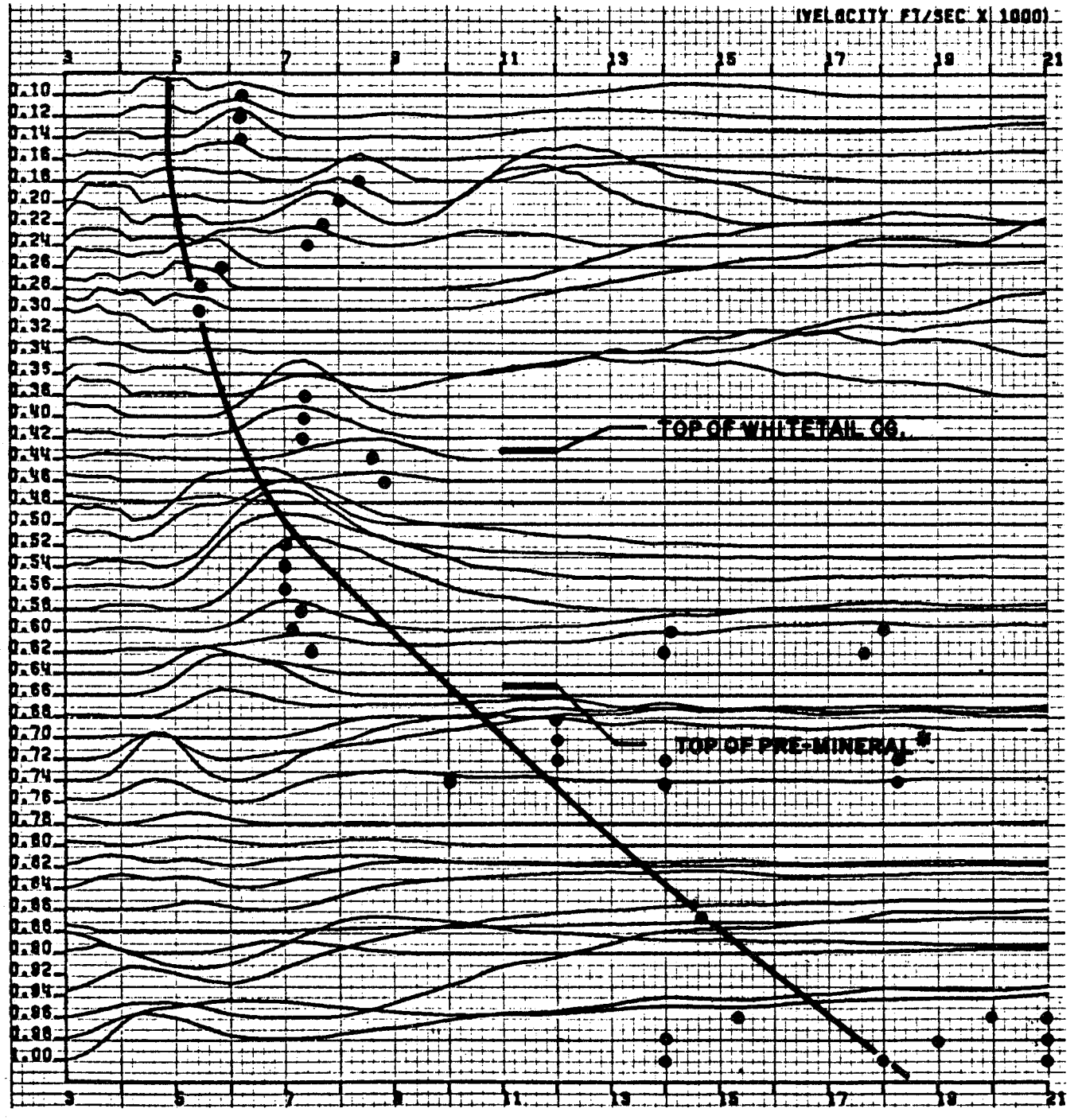
*Half of reflection points are down-dip on slope from shot point.

Plate 2 – Line N, Velocity Profile Shot Point 2



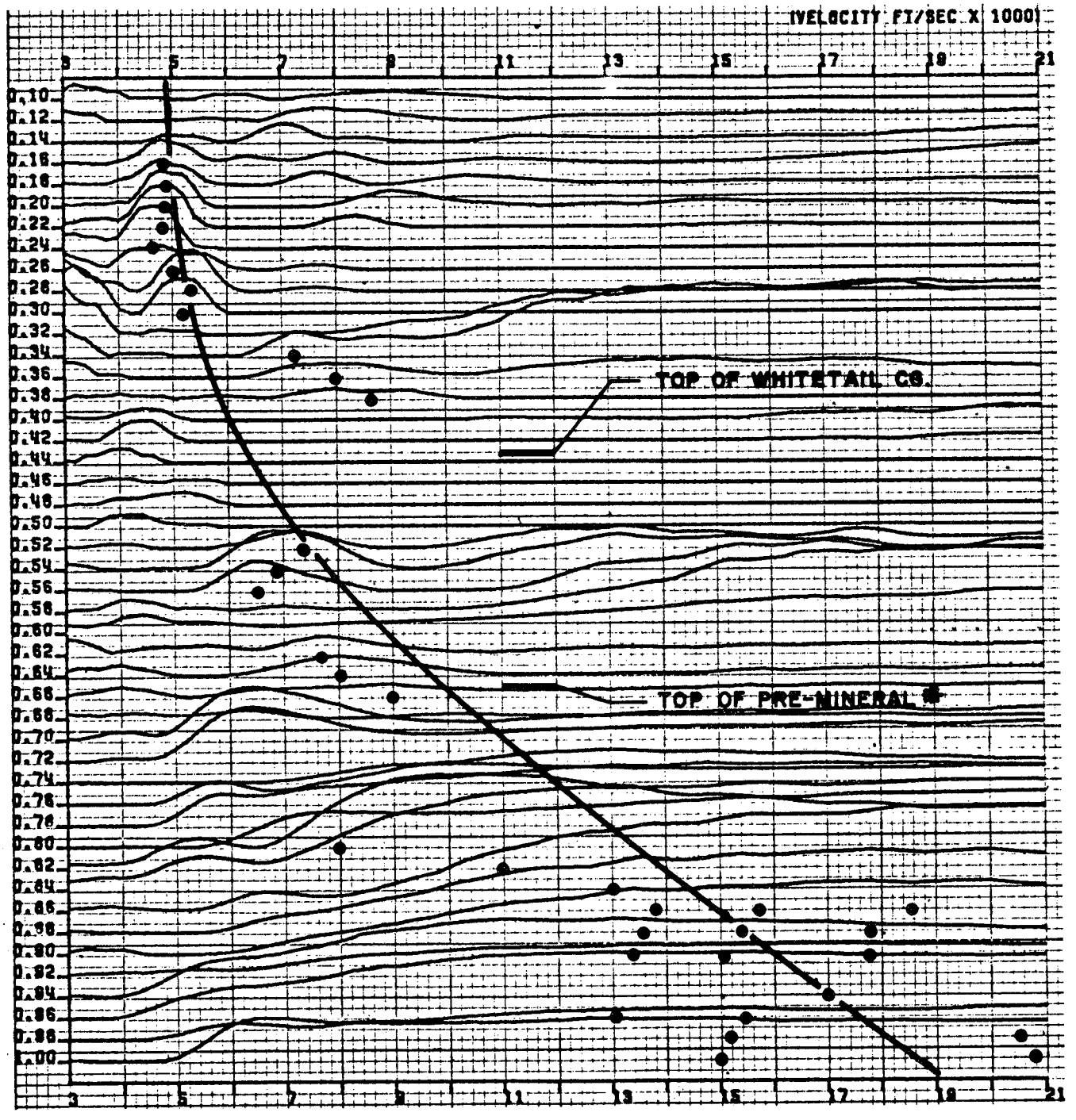
*Half of reflection points are up-dip on slope from shot point.

Plate 3 – Line I-1, Velocity Profile Shot Point 1N



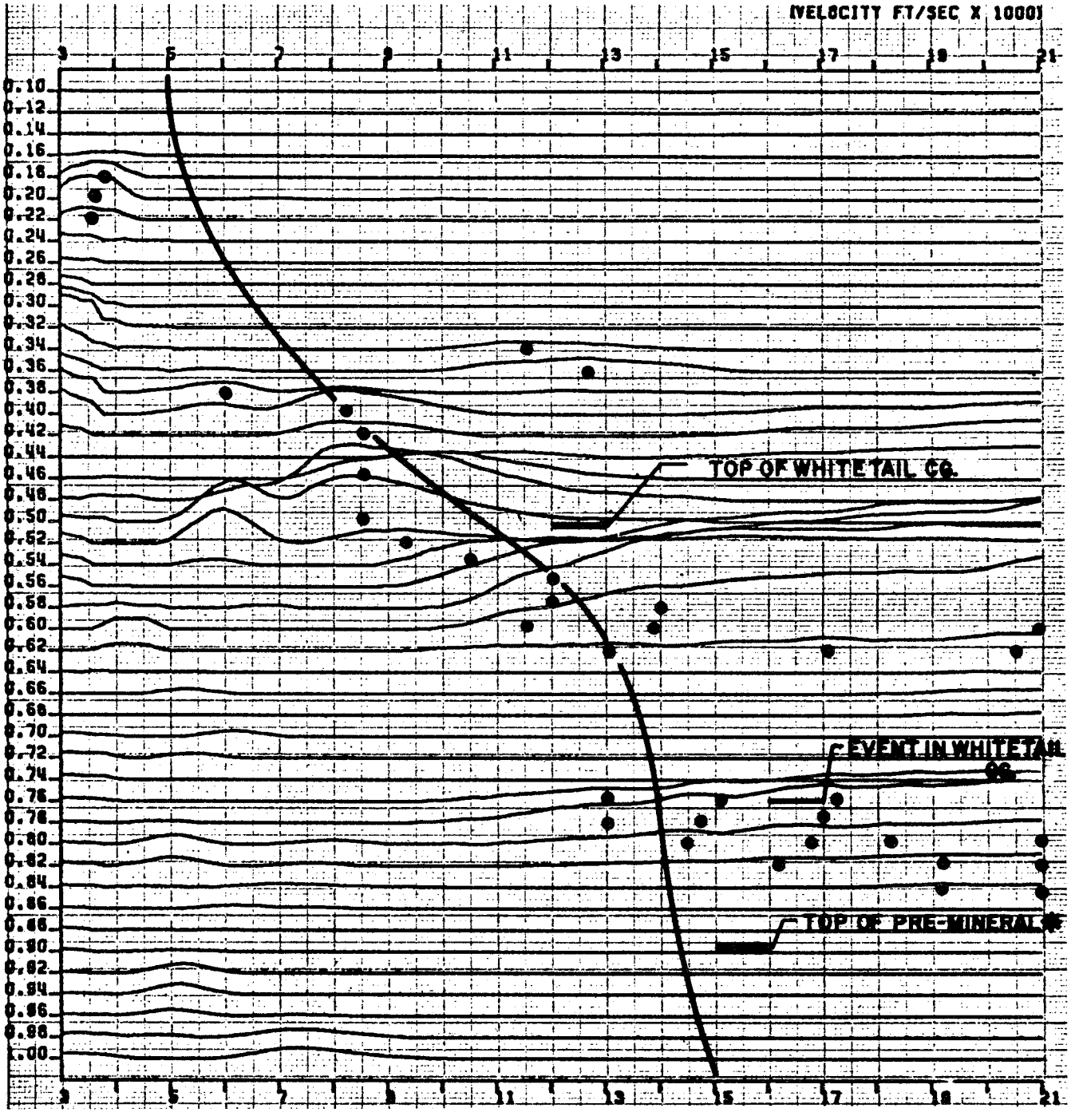
*Top of host rock assemblage is evident as an event on seismic trace section.

Plate 4 — Line I-1, Velocity Profile Shot Point 3S



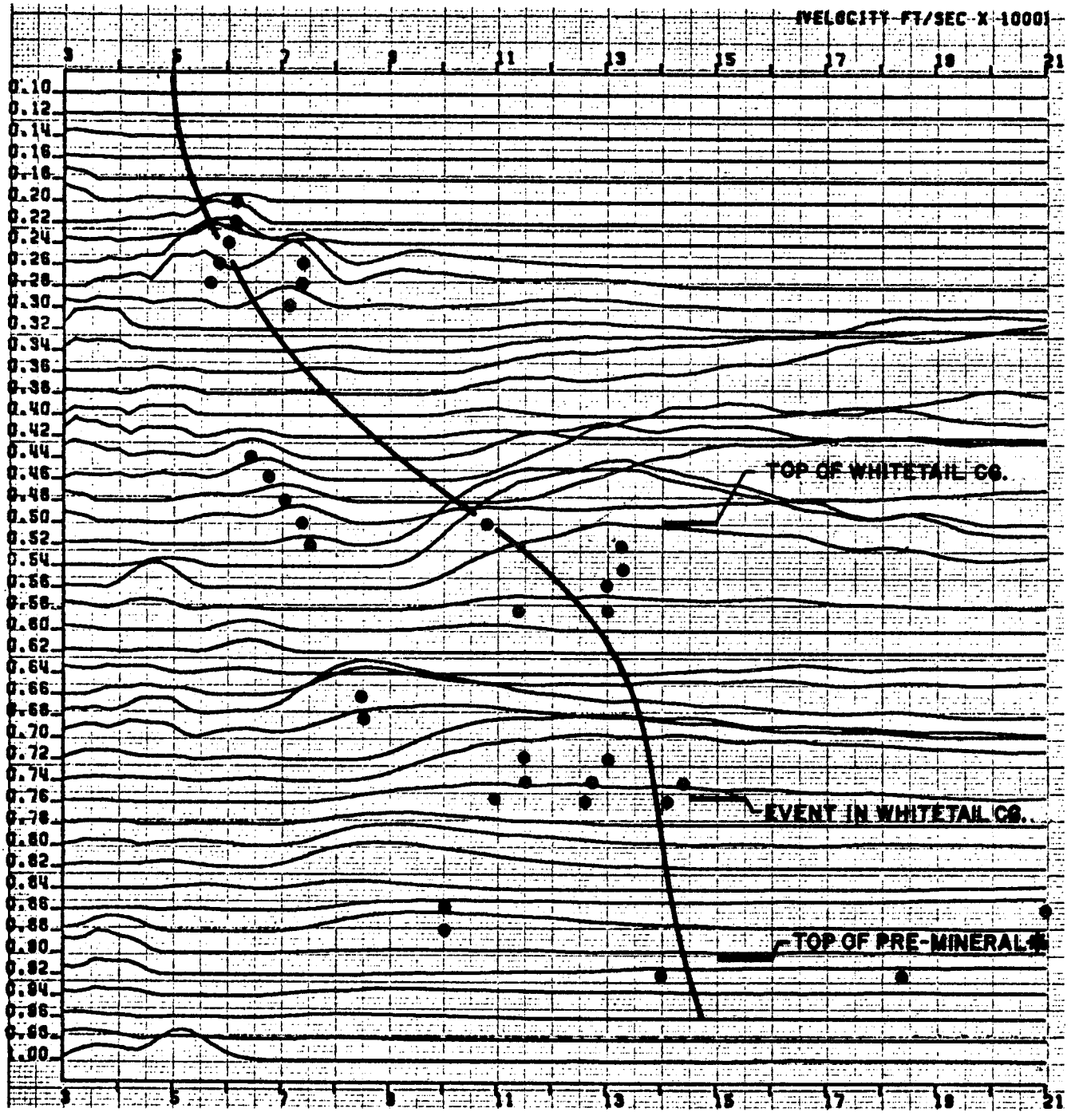
*Top of host rock assemblage is evident as an event on seismic trace section.

Plate 5 – Line C, Velocity Profile Shot Point 8S



*Top of host rock assemblage is evident as an event on seismic trace section.

Plate 6 – Line C, Velocity Profile Shot Point 8N



*Top of host rock assemblage is evident as an event on seismic trace section.

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

February 22, 1972

Mr. C. K. Moss
Salt Lake City Office

Enclosed is a final report by J. W. Cooksley on his seismic work at our Superior East project. Also enclosed is Mr. Sell's covering letter to me. I would appreciate it if you would very critically review this report.

As pointed out by Mr. Sell, the velocity profile (Plate 1 - Appendix C) is critical in Mr. Cooksley's interpretations and it appears to me that the positioning of this curve is much more of an art than science. If truly all geophysicists would construct this curve in nearly the same position, then perhaps Cooksley has arrived at a feasible method of determining major rock contacts in an extremely complex area such as the dacite plateau. Again, as Mr. Sell points out, Cooksley's method, if it works, is usable only at a specific shot point. This would provide usable data for us since we could use it in the same manner as we do a drill hole in constructing a cross section.

If you do indeed believe there is some definite merit in Cooksley's method, I believe additional work should be done to prove the method. Such work could be conducted by Cooksley or by your organization if you do have the capabilities. I would recommend a research project by your office to do this work.

Very truly yours,

W. L. Kurtz

W. L. Kurtz /lad

WLK:lad
Encs.

cc: JJCollins - w/o enc.
JHCourtright - w/o enc.
JDSell - w/o enc.

EXPLORATION SERVICES DIVISION
3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

RECEIVED
MAR 6 1972
S. W. U. S. EXPL. DIV.
W. L. K.
MAR 10 1972

March 2, 1972

Mr. W. L. Kurtz
Tucson Office

Dear Bill:

This will acknowledge receipt of your letter of February 22 transmitting J. W. Cooksley's report on his seismic work at Superior East.

I would like to consider this report for a short period before making reply to your suggestions.

Yours very truly,

Cal

CKM:am

C. K. MOSS

cc: J. J. Collins
J. H. Courtright

EXPLORATION SERVICES DIVISION
3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

March 27, 1972

Mr. W. L. Kurtz
Tucson Office

COOKSLEY SEISMIC REPORT
SUPERIOR EAST PROJECT
FEBRUARY 1972

Dear Bill:

I would like hereby to discuss the subject report in light of your letter of February 24, and in amplification of our intervening phone discussion.

As we all would conclude after studying the seismic data, Cooksley's interpretations include a high percentage of subjective content. It would not necessarily follow directly that his interpretations would be questionable, since he has unique experience in this work, and might have singular ability in evaluating the data.

An accurate interpretation of the seismic data depends upon the correct evaluation of two aspects of the problem. First the interpreter must be able to find a diagnostic character for reflection events on the seismic record which he can definitely attribute to identifiable interfaces of the geology; second he must have reasonably accurate velocity information for waves traveling through the respective intervals of the section.

As you point out, if a second geophysicist were able independently to make the same interpretations as Cooksley then the credence for the work would be enhanced. In lieu of a second interpreter, if Cooksley's interpretations over different portions of the ground were consistent with the geology as known from drilling, and if the results of his work predicted reasonable values for seismic velocities as compared with reference tables on this subject, then credence could be established on this basis.

I have tried to take the role of interpreter to compare my results

with Cooksley's; however, I am unable to assure myself that I can find distinctive characteristics in the seismic record with which to identify specific parts of the geologic section. Consequently, I can not support Cooksley's correlations. On the other hand, I cannot disprove his correlations -- overall, though, I retain considerable skepticism as to their validity.

In regard to the velocity logs which he derives from the computer data (again involving the subjective factor), I have re-worked his logs for the three profiles on the project. My motive in re-working his data is to show the actual velocity which his logs predict for the different rocks, rather than the average velocity from the surface to the horizon of interest, which his velocity log shows directly.

Attached are the graphs of my work which are based on his velocity logs. One can readily note the great range in velocity for the same section of geology, under different points on the Plateau. This large variation from one traverse to the next seems excessive. A second questionable feature on the graph relates to the extremely high velocities (plus 25,000 ft. /sec.), which come from his log. These velocities in turn seem excessively high.

In summary, while I personally question that Cooksley can identify reflections from particular geologic sections, I cannot completely refute this possibility. However, even granting that he can, I estimate that his velocity error could result in depth errors of 25%.

Up until this time, most of Cooksley's interpretations have had the benefit of prior knowledge of the geology. The best test to which we can subject Cooksley's work is in the field, by comparing his unbiased interpretation with known drilling results (as you and Jim have proposed). An alternate form of a test would be for us to supervise his field crew and use cross-spreads and parallel spreads for his interpretation, without his knowledge of the relative position of the measurements.

Further concern with this problem, of course, is dependent upon your continuing need of the type of data which seismics might provide on the Plateau.

CKM:am
Enc.
cc: J. J. Collins, wo/enc.
J. H. Courtright wo/enc.
J. D. Sell, w/enc.

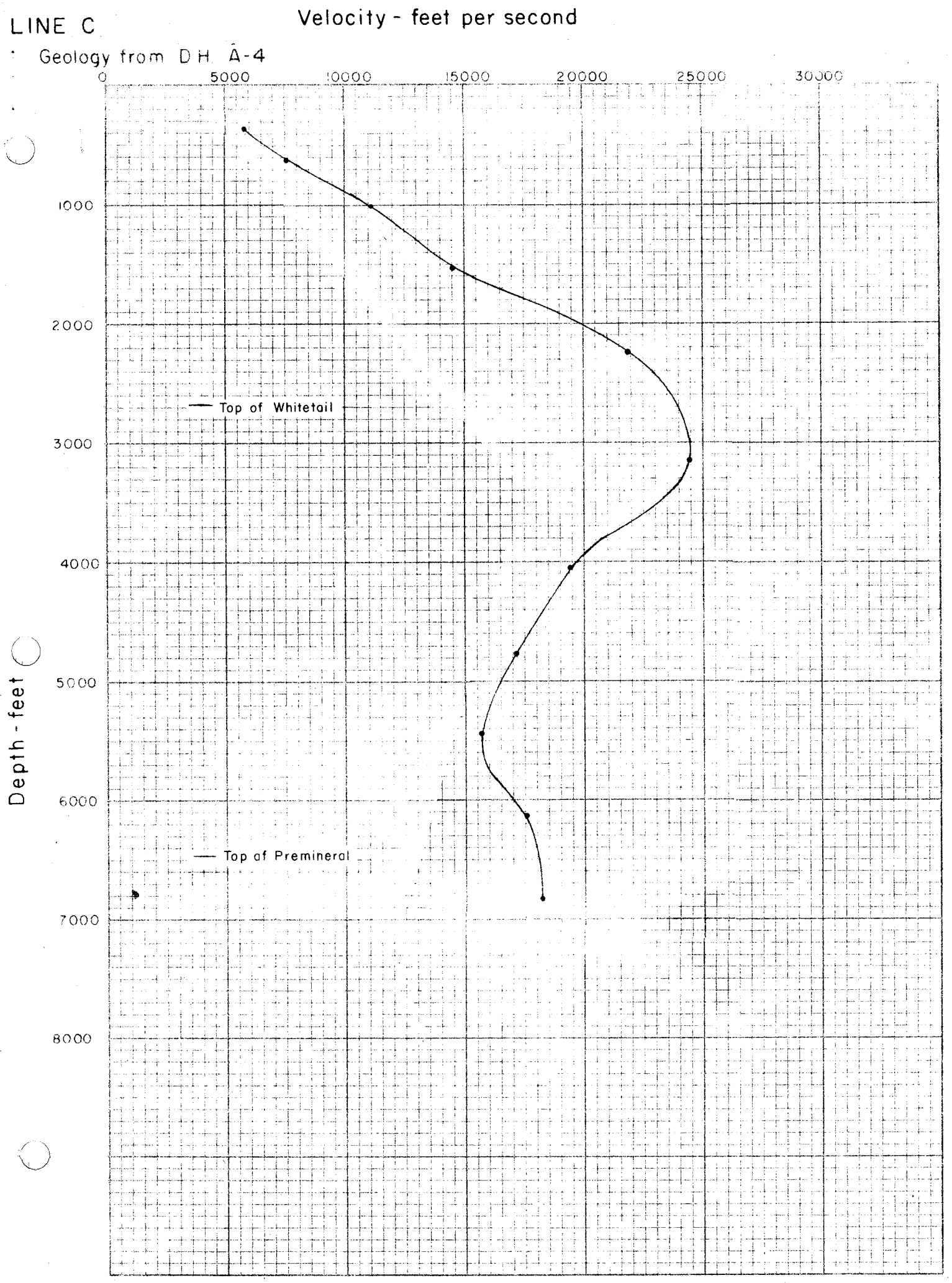
Yours very truly,

Cal Moss

C. K. MOSS

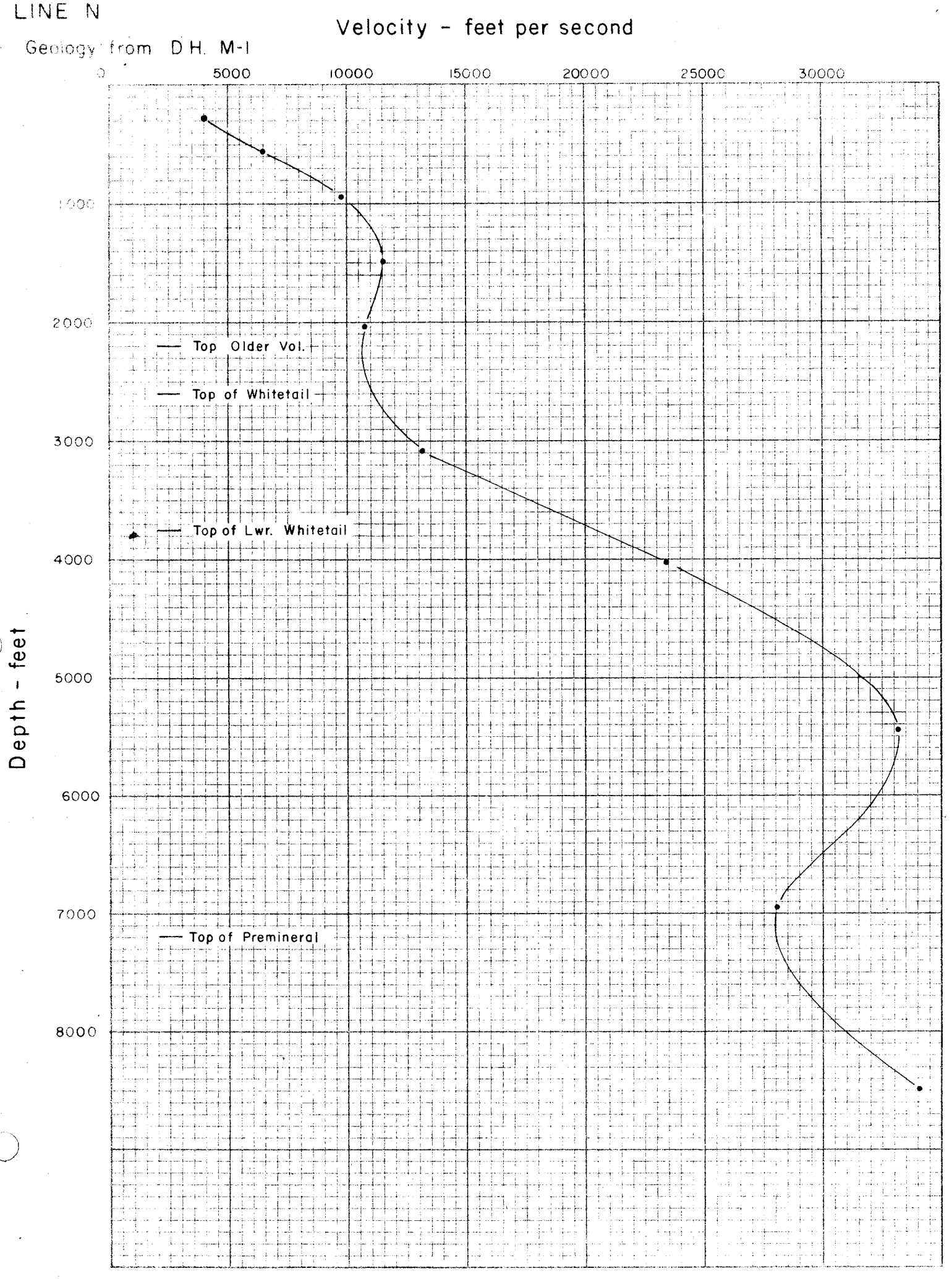
LINE C

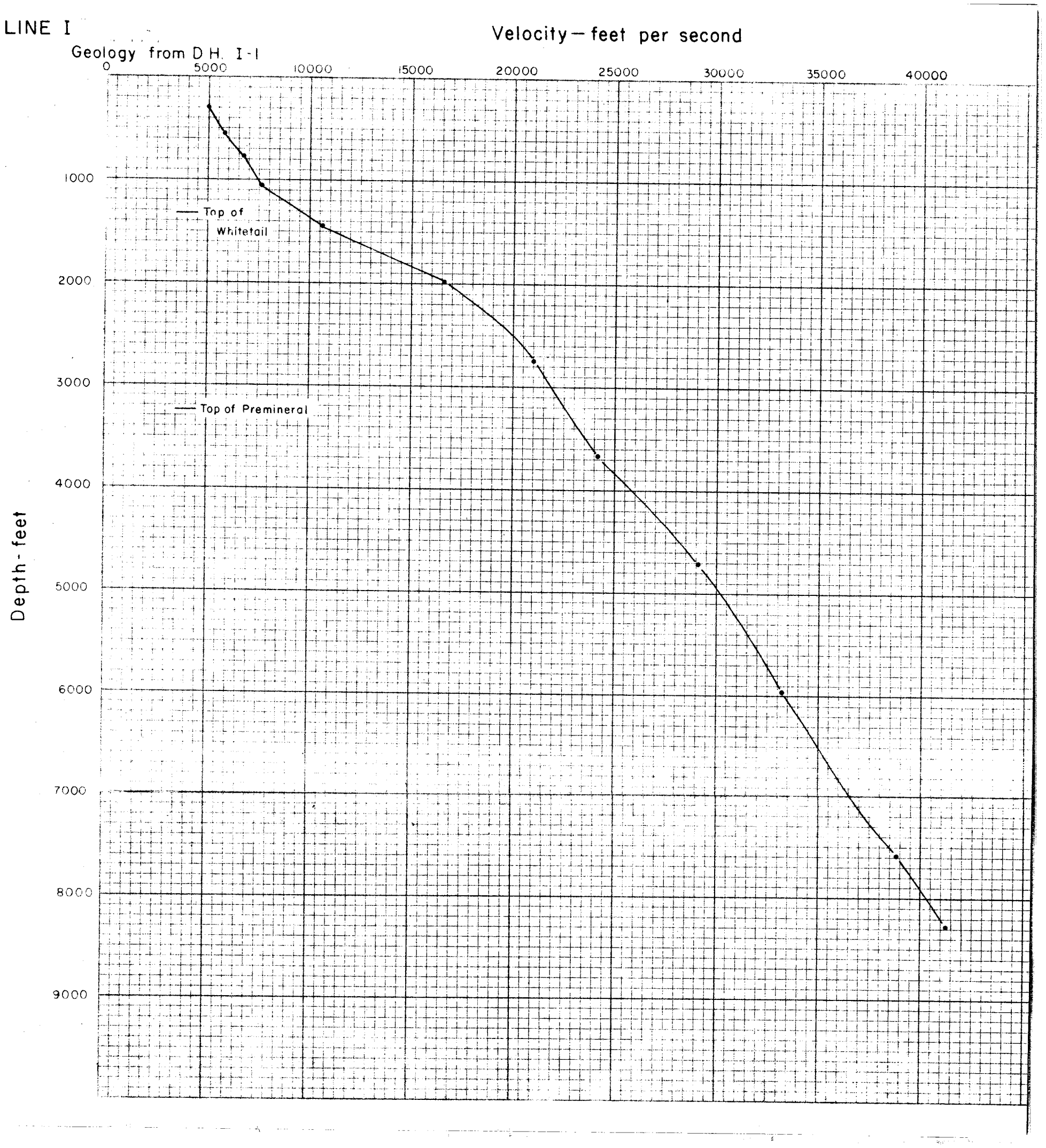
Geology from DH A-4



LINE N

Geology from D.H. M-1




LINE I
Geology from D.H. I-1
Velocity — feet per second
0
5000
10000
15000
20000
25000
30000
35000
40000
1000
2000
3000
4000
5000
6000
7000
8000
9000
Depth - feet
Top of Whitetail
Top of Premineral

W. L. K

DEC 3 1973

J. W. COOKSLEY, JR.
Geophysicist - Geological Engineer

APPLIED EARTH SCIENCES

2610 East Grant Road
Tucson, Arizona 85716
(602) 795-9790

RECEIVED
DEC 3 1973
S. W. U. S. EXPL. DIV.

30 November 1973

American Smelting & Refining Company
Southwestern Exploration Division
Post Office Box 5747
Tucson, Arizona 85703

Attention: William L. Kurtz

In accordance with your suggestion, this proposal is being written concerning further seismic studies on the dacite plateau between Superior and Globe, Arizona. This proposal is a result of our meeting during the afternoon of Thursday, 29 November 1973, during which I suggested that ASARCO consider applying the "bright spot" technique, which has enjoyed much success in petroleum exploration, to locating mineral exploration targets. In the course of the discussions with yourself and Mr. Sell, it was concluded that any such program should be preceded by a preliminary evaluation of the seismic data previously shot in the area. The following proposal is set forth in phases so as to logically assess the overall program stepwise regarding feasibility, accuracy, progress and cost.

PHASE I This phase would entail inspecting and evaluating all the data available on Line N. This line has been recomputed by a second computer data reduction service and has much additional processing in addition to the normal data reduction. We propose to derive a seismic section in time domain showing areas which seem most favorable for bright spot studies. The cost of this phase is estimated to be $250.00.

PHASE II If the studies of Line N indicate usable new information concerning the application of bright spot (or other heretofor overlooked exploration criteria), the seismic data from the other lines will be reviewed and re-evaluated as was that on Line N. The cost of any such work would amount to $200.00 per line. If after consulting with yourself it was agreed that further computer analysis was needed, the cost of the computer work would be added. Such work would probably amount to less than $300.00 per line. The lines available for such analysis are A, B, C, D, and M from the old "Continental" program, and

Section 4, Section 5, and I from the work conducted for ASARCO during the spring and summer of 1971. If no additional computer service is required, the total cost of reviewing all the remaining lines would be about $1,600.00.

PHASE III This phase would consist of applying updated velocity functions to all the work accomplished on the subject area and to draw a revised structural contour map of the top of pre-mineral rock. If no additional velocity information is needed, the cost of such work would be about $1,000.00.

PHASE IV If the results of the previous phases warrant, this phase would entail the design and execution of seismic field and computing operations directed toward obtaining relative amplitude data (bright spot). Costs of this work should be estimated on the basis of about $2,500.00 per line-kilometer (3,280 feet) of traverse. Aerial coverage, e.g., a square kilometer, would have to be estimated on an individual basis, depending on degree of resolution required and the field conditions.

The estimated costs shall be used as not-to-exceed costs and would be exceded only upon written approval by yourself or the designated project manager. This office would accomplish the computing and furnish reports of findings on all phases.

Thank you for considering our firm for work on this project.

Sincerely,

James W. Cooksley, Jr.

J. W. Cooksley, Jr.
Geophysicist

JWC/ksk

return to → To J. Sell. DEC, 1973 209

Copy for WCK FILES

REFLECTION SEISMIC INVESTIGATION

OF SUBSURFACE GEOLOGY

AT THE SUPERIOR EAST PROJECT

GILA AND PINAL COUNTIES, ARIZONA

CONDUCTED FOR

AMERICAN SMELTING AND REFINING COMPANY

by J.W. Cooksley, Jr.
2410 East Grant Road
Tucson, Az 85716

INTRODUCTION

This investigation is an expansion of a reflection seismic exploration program conducted on the Margaret claim-group during January - March, 1970 for Continental Copper, Inc. A report of investigation covering the initial project titled, Reflection seismic survey conducted on the Margaret claims located about four miles northeast of Superior, Arizona, was completed by this office and submitted to Continental Copper, Inc. in June, 1970. Since this time, American Smelting and Refining Company has taken over the exploration of the Margaret claims and some adjacent lands.

The seismic exploration in this area has been directed primarily toward finding the contact between the underlying pre-mineral assemblage of sedimentary, igneous and metamorphic rock units, and an overlying section of post-mineral volcanics and continental sedimentary units which measures in excess of 5,000 feet locally. Additional effort has been directed toward differentiating pre-mineral and post-mineral faulting, and in determining the type of rock present in the pre-mineral assemblage.

Much has been written about previous exploration, mining activities, geology and ore deposits in the Superior and the Globe-Miami mining districts. The reader is referred to works by Peterson, D. W. (1969), Hammer, D. F. and Peterson, D. W. (1968), Peterson, N. P. (1962), and Ransome, F. L. (1903 & 1914) which contain detailed descriptions of these subjects. This report, being primarily a description of the findings of the reflection seismic exploration, will treat only those items which are directly related to seismic interpretations.

Since the completion of the initial seismic work conducted for Continental Copper, Inc., two deep drill holes have been completed, and one is currently being drilled. The results of the drilling indicate that the

seismic work is in serious error west of the Margaret fault, but seems to be accurate to within ten (10) percent east of this structure. The Margaret fault is a north-striking normal fault, the west block down-thrown, which was interpreted from the seismic data. Apparently a large accumulation of Whitetail Conglomerate, a post-mineral, continental, sedimentary deposit, is present west of the Margaret fault. The velocity of this unit was greatly underestimated, thus resulting in an erroneously smaller depth calculation to the top of pre-mineral rock.

GEOLOGIC SETTING

Sequence of Rocks

		Lithology	Thickness	Velocity
POST-MINERAL	TERTIARY	Apache Leap Tuff -- predominantly dacitic tuff units, vitrified & devitrified.	1,000 to 2,000 feet	5,000 to 8,000 fps
		Unconformity		
		Older Volcanics -- predominantly andesitic to basaltic flow and tuffaceous units.	0 to 600 feet	10,000 (?) fps
		Unconformity		
		Whitetail Conglomerate -- continental conglomerate deposit in predominantly shaly to sandy matrix, well bedded to poorly bedded.	0 to 3,000 + feet	10,000 to 17,000 (?) fps
		Unconformity		
PRE-MINERAL	PENNSYLVANIAN	Naco Limestone -- Medium- to thin-bedded limestone that locally contains irregular nodules and layers of chert, and fissle shale sporadically interbedded with limestone. Bedding planes distinct and predominately flat, though some are wavy. Locally mineralized in the Globe area.	0 to 1,000 feet	12,000 to 14,000 fps (assumed)
	MISSISSIPPIAN	Escabrosa Limestone -- Thick- to thin-bedded limestone. Upper Escabrosa is medium- to thin-bedded and contains abundant chert and interbedded shale. Middle	400 to 500 feet	12,000 to 14,000 fps (assumed)

	Lithology	Thickness	Velocity
PRE-MINERAL	Escabrosa is thick-bedded and is cliff forming. Lower Escabrosa is thick- to medium-bedded. Mineralization occurs locally in Globe and Superior areas.		
DEVONIAN	Martin Limestone -- Alternating zones of thin- to medium-bedded limestone and dolomite. Thin beds of medium-grained quartzite, sandstone, and shale interbedded with limestone and dolomite in lower section. Upper limit of Martin defined by 10 - 30 feet of highly fissile calcareous shale. Medium-bedded dark-gray crystalline limestone is host rock for replacement ore bodies in Magma Mine and is locally mineralized elsewhere.	350 to 450 feet	12,000 to 14,000 fps (assumed)
	Disconformity		
CAMBRIAN	Bolsa Quartzite -- Upper part - medium to fine grained quartzite that may grade locally to sandstone. Bedding distinct, medium to thick, generally even, locally undulating; crossbedding common. Lower part - heterogeneous clastic lithologies varying abruptly both laterally and vertically.	0 to 430 feet	
	Unconformity		
	Diabase -- Sills and dikes. Generally medium grained, locally course grained, aphanitic at		15,000 to 22,000 fps (assumed)

	Lithology	Thickness	Velocity
PRE-MINERAL / PRECAMBRIAN	chilled borders. Commonly, minerals moderately altered. Intrudes Troy Quartzite and older formations, and is depositionally overlain by Bolsa Quartzite.		
	Stratafied Precambrian Formations -- These include the Troy Quartzite (730 ft.), Basalt (max. 320 ft.), Mescal Limestone (350 ft.), Dripping Spring Quartzite (720 ft.), and the Pioneer Formation (305 ft.).	2425 feet	15,000 to 22,000 fps (assumed)
	Unconformity		
	Pinal Schist -- Quartz-muscovite schist and quartz-muscovite-chlorite schist. Well-developed to indistinct foliation that is slightly to intensely contorted. Pods, veins, and veinlets of white quartz locally abundant.		15,000 $\pm$ fps (assumed)

FINDINGS OF SEISMIC INVESTIGATION

The seismic exploration program was based on the premise that a detectible seismic discontinuity was present along faults and at the base of the superjacent units. It seems reasonable to expect that the elastic properties of the rock in proximity of faults and in the superjacent units are sufficiently different from those in the intact rock and in the underlying pre-mineral units to constitute the potential for obtaining discernable seismic discontinuities.

Correlation of Seismic Velocity with Geologic Units

The determination of average velocity is a rather complex procedure of interpreting reflection velocity analysis data as scanned with digital correlation methods. It has been our experience that using an analysis from only one shot point would invariably be misleading in at least one aspect and maybe in several. However, inspection of many velocity analyses simultaneously yields a more rational and complete interpretation of seismic velocity and geology.

Velocity analysis data indicates velocities in the Apache Leap Tuff range from 6,000 fps at the surface to as much as 8,000 fps at the base of the section. Interpreting from average velocity data, the seismic velocity of the Whitetail Conglomerate appears to be in the order of 10,000 fps to 12,000 fps. Velocities in pre-mineral assemblage rocks probably range from 14,000 fps to 20,000 fps where the rock is not affected by alteration or fracturing. The average seismic velocity which predominates at the base of the post-mineral sequence is about 10,000 fps, and this has been the velocity used to compute the depth to the pre-mineral rocks.

Mapping Faults

In this project, mapping faults is critically important in the interpretation of the seismic data. Pre-mineral faults do not transect the Whitetail Conglomerate or the Apache Leap Tuff. Hence the upward termination of these faults, if properly identified, can be used to interpret the discontinuity existing at the top of the pre-mineral assemblage. Post-mineral faults affect greatly the configuration of the unconformity at the top of the pre-mineral assemblage, so the movement on these structures must be known in order to map the top of pre-mineral rock.

Both pre-mineral and post-mineral fault structures are interpreted from the seismic data taken along the seismic traverses. An easterly strike is assumed on the pre-mineral faults and generally northerly strikes are assumed on the post-mineral faults. The basis for the strike of the pre-mineral faulting is the easterly strike of the Magma fault and the east-trending mineral belt which has been mapped and recognized by many

to encompass the major ore deposits at Superior, Arizona, to the west and the Globe-Miami area to the east. The northerly strikes, and the dips of the post-mineral faults are interpreted from the rather sparce seismic coverage at hand, from faulting mapped at the surface by Peterson, D. W. (1969), and from drill hole data made available to this office.

Seismic Section C-C'

Pre-mineral Rock Units

The elevation of the unconformity at the top of the pre-mineral rock ranges from about 400 feet at Station 1,500 down to about -300 feet at Station 3,500. The configuration of the unconformity if relatively flat.

Reflection discontinuities indicate the presence of stratified rock units immediately below the unconformity at the top of the pre-mineral units. These units are thought to be sedimentary formations of Paleozoic and Precambrian age, possibly intruded by diabase sills and dikes.

Pre-mineral Faults

At least three structures interpreted to be pre-mineral faults appear between Station 2,000 and Station 4,000 on Line C. The largest of these structures intersects the unconformity at the top of the pre-mineral assemblage at Station 3,500, displacing the unconformity about 200 feet downward on the south side. Below the unconformity, the seismic discontinuities, which probably represent bedding in Paleozoic and Precambrian strata, are displaced about 1,000 feet down on the south side. A possible speculation might be made concerning this structure, that is it might be the easterly extension of the Magma fault. There are two pre-mineral faults to the south of this structure; speculating again, possibly being correlative with the South Branch vein at the Magma mine or the Lake Superior and Arizona vein. A pre-mineral discontinuity to the north of the largest structure appears to have slight reverse movement. The elevation of the discontinuity at the top of pre-mineral rock at the largest structure appears to be about -250 feet.

Post-mineral Faults

Three post-mineral, normal faults intersect the top of the pre-mineral assemblage at, from south to north, Station 1,500, Station 2,600, and Station 3,400. The strikes of the faults at Stations 1,500 and 2,600 range from 20° to 30° west of north. The strike of the fault at Station 3,400 is about N35E. The intersection of these faults appear to form the corner of a block which has been down-thrown to the east. The largest of the pre-mineral faults appears to be intersected by the post-mineral fault at Station 3,400.

Seismic Section at Section 5

Pre-mineral Rock Units

Seismic readings indicate the elevation of the top of pre-mineral rock to range from 1,300 feet down to 800 feet along one set of reflection points, and from 1,300 feet down to 900 feet on another set of reflection points roughly parallel and about 500 feet to the east of the first set. Because of curvature in the line of seismic sensors, a northwest striking post-mineral fault was cut twice by both sets of reflection points. The top of pre-mineral rock is downthrown to the northeast from 100 to 250 feet or more.

Nearly-parallel lines of reflection events suggest that the pre-mineral assemblage is comprised of stratified rock units, probably in large part Paleozoic and Precambrian sedimentary formations. A sinuous, but fairly continuous reflection event can be traced discordantly across the stratified reflection events. This discordant event dips to the south and appears to be offset or at least influenced by pre-mineral structures. Tentatively, this event is interpreted to be the top or base of a diabase intrusive.

Pre-mineral Faults

Two pre-mineral faults are interpreted in the interval between Station 1,400 and Station 2,200 on one line of reflection points and in the vicinity of Station 1,600 and Station 2,000 on the other line of points to the east. The easterly strikes of these two structures were subsequently inferred from their intersections with the two lines of reflection points.

Post-mineral Faults

The main post-mineral structure is referred to above in the first paragraph under Pre-mineral Rock Units.

Seismic Section at I-1

Pre-mineral Rock Units

According to the seismic data, pre-mineral rock is encountered at elevations ranging from 2,300 feet down to 1,100 feet along this seismic section. Drill hole I-1 is at the south end of the section and here, the seismic data correlates well with the drill hole data. Between Station 0 and Station 2,500 and the north end of the traverse at Station 3,500, the unconformity is step-faulted upward to the north from an elevation of 1,300 feet to an elevation of 2,300 feet.

The random nature of the seismic discontinuities in the pre-mineral assemblage suggest that the Pinal Schist of Precambrian age, probably

cut by intrusives of Precambrian and Laramide age, is the predominant rock type.

Pre-mineral Faults

Two nearly-vertical pre-mineral discontinuities were plotted -- one near Station 1,200 and the other near Station 3,200. These structures are believed to be faults.

Post-mineral Faults

Post-mineral normal faulting offsets the top of the pre-mineral assemblage at Station 1,000, Station 2,000, Station 2,600 and Station 3,200. The northwest strike of the faults at Station 2,600 and Station 3,200 was ascertained by observation of their presence along two nearly parallel lines of reflection points. Displacement on both these faults is in the order of two hundred feet, the south side being down-thrown. Displacement on the other two faults appears to be less than 100 feet, again the south side downthrown.

Seismic Section at Section 4

Pre-mineral Rock Units

The top of pre-mineral rock is interpreted to be between elevation 800 and 1,700 along this traverse. Both pre-mineral and post-mineral faults are in evidence, the post-mineral faults having a large effect on the topography of the surface of the pre-mineral rock. A greater density and continuity of reflection events at the pre-mineral surface indicate the presence of stratified or tabular rock units. These units are believed to be sedimentary and volcanic units of Paleozoic and/or Precambrian age, but they might also be a series of gently-dipping, tabular diabase intrusions in Pinal Schist. These units appear to attain a thickness in excess of 2,000 feet at the south end of the traverse, but seem to pinch out to less than 500 feet at the north end. The rock underlying these units is interpreted to be Pinal Schist, possibly intruded by Precambrian diabase and Laramide granitic rock.

Pre-mineral Faults

Pre-mineral fault structures are interpreted at Station 2,800 and Station 4,500. Several northeast-trending, mineralized structures have been mapped in Pinal Schist where it crops about 5 miles to the east and northeast of this traverse (Peterson, N. P., 1961). The fault encountered at Station 2,800 appears to be vertical, the north side downthrown about 100 feet. The fault at Station 4,500 appears to dip very steeply to the north, the south side being downthrown about 100 feet.

Post-mineral Faults

Three post-mineral faults were mapped from the seismic data. Because of the lack of a parallel set of reflection points, the strikes of these structures are very questionable, being based on sparce geologic data. One rather large normal fault intersects the top of pre-mineral rock at Station 2,300. With a northwest strike being inferred on this fault, the southwest side is downthrown about 500 feet. Another rather large normal fault is at Station 4,000; the inferred strike is due north and the east side is downthrown about 300 feet. A fault with less movement was mapped at Station 5,200, the inferred strike being due north and the east side being downthrown about 100 to 200 feet. It seems quite possible that, the fault at Station 2,300 might be a branch of the large north-trending Margaret fault zone.

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3. Peterson, D. W., 1962, Prelininary geologic map of the western part of the Superior quadrangle, Pinal County, Arizona: U.S. Geol. Surv. Mineral Inv. Field Studies Map MF-253, 1:12,000.

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7. Ransome, F. L., 1903, Geology of the Globe copper district, Arizona: U.S. Geol. Surv. Prof. Paper 12, 168 p.

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Cockley Seismic Interp.

4/15/74

DCA-3

base of Td @ 1500'

Strong discontin @ 1900'

Thickness of Tw = 1200 ft.

3500
-1200
2300 base of Tw.

Top of bedrock (slide) @ 3500'

block wedges out toward west

Base of slide @ 3700-3800'

Isopach Sell

base of Td @ 1490 (known)

base of Tw @ 2430 (known).

~~base of Tw @~~

Thickness of Tw = 1138 ft (isop.)

Top of bedrock (slide) = 3565 ft. (isop.)

Base of slide at 3715 ft. (isop.)

log

0-1490 Td

1490-2430 Tw

2430 - 4081 Tw

4081 - 4159 Tgm-pesc slide (78') — top of slide seismic?

say 4080
x = 3500
580' diff. or $\frac{580}{4080}$ = 14 %

$\frac{580}{3500}$ = 17%

20 24

4159 - 4297 Tw (138')

4297 - 4394 Tgm slide (97')

4394 - 4454 Tw — top of br seismic?

say 4450
x = 3800
650 diff or $\frac{650}{4450}$ = 15 %

$\frac{650}{3800}$ = 17%

4454 - 4666 Tgm wood? (212')

4670 - 4806 Tgm or Bt720

4809 - 4948 pepi crude?

4953 - 5154 pepi

EXPLORATION SERVICES DIVISION
3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

May 20, 1974

Mr. Jim Sell
Tucson Office

Dear Jim:

John Collins has asked whether the seismic work as described by Superior Oil in the attached article would be useful in Asarco's Superior East Project.

Of course, we do have the results of Cooksley's work in the area, which did not come up to expectations; but two questions occur to me after reading the article: (1) would seismics be more effective if the work concentrated on getting information on the sedimentary section relative to the "vein-fault", rather than trying to see through this section; (2) would Superior Oil have a sufficient advantage over Cooksley in seismic know-how to make the difference between success and failure?

Have you any thoughts on the matter?

Yours very truly,

Cal

C. K. MOSS

CKM:am
Enc.

cc: W. L. Kurtz, wo/enc.

AMERICAN SMELTING AND REFINING COMPANY
TUCSON ARIZONA

June 3, 1974

Mr. C. K. Moss
Exploration Services Division
Salt Lake City Office

Seismic
Superior Oil Article
Superior East Project
Pinal County, Arizona

Dear Cal:

In reply to your inquiry of May 20th on Ted Eyde's article, J. W. Cooksley did all the seismic for Superior Oil and, as I gathered from the story, he also did most of the interpretation, although others were involved. I also gather that Cooksley was very happy with the diabase response and interpreted much from that approach. As shown on Eyde's Fig. 2, the nearly 2000 feet of displacement across the Magma vein-fault would allow a greater leeway in interpretation, when that is the magnitude of the overlying cover rocks and having a relatively thin section of Whitetail.

I feel that seismic can probably help in determining premineral, and perhaps most rock units, their configuration and distribution. Certainly Cooksley has indicated that with more subsurface control he is willing to show probable faults and various rock units. I also feel that, to fully benefit from any further work, a very widespread program must be utilized to give enough control through the data points now available. Certainly, as Cooksley has pointed out, various orientations are necessary to pin down the fault structures, and it would probably be necessary to run additional lines in a more advantageous orientation to fully appreciate the data being gathered.

I also feel that, in the Superior East project proper, the extreme changes in Whitetail thicknesses and lateral character will pose a problem on overall interpretation.

Mr. Kurtz feels that our drilling to date has fairly well established the general overall configuration of the Whitetail basin and general distribution of the rock types. He feels that additional seismic work would be more of a research project and not directly applicable to guiding further exploration at Superior East.

Sincerely,

James D. Sell

James D. Sell

JDS:lb

cc: WLKurtz

EXPLORATION SERVICES DIVISION
3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

June 6, 1974

Mr. J. J. Collins
New York Office

Dear John:

Recently you inquired whether seismic work could be useful at Superior East as per the work done by Superior Oil and described in A.I.M.E. Transactions, March 1974.

You will recall that the Tucson group had seismic work conducted on the Plateau a few years ago -- although the objectives were somewhat different than Superior's.

At any rate I corresponded with Jim Sell, who, it turns out, is quite knowledgable about Superior's seismic survey. His general conclusion, regarding your question can be best quoted:

> "Mr. Kurtz feels that our drilling to date has fairly well established the general overall configuration of the Whitetail basin and general distribution of the rock types. He feels that additional seismic work would be more of a research project and not directly applicable to guiding further exploration at Superior East."

Yours very truly,

Cal Moss

C. K. MOSS

CKM:am

cc: R. J. Lacy
W. L. Kurtz - J. Sell ✓

JHC, JDS

W.L.K. JUN 17 1974

RECEIVED JUN 17 1974 S. W. U. S. EXPL. DIV.

Air Mail

June 13, 1974

Mr. C. K. Moss
Exploration Services Division
Salt Lake City

Superior East, Arizona

Dear Mr. Moss:

Your note of June 6 on seismic work on the Dacite Plateau caused me to review the file. Your March 27, 1972 review of Cooksley's seismic report is not conducive to much confidence in the results. Apparently the seismic surveys by Superior Oil were much more significant. Unless we had access to similar standards, I would agree that it is useless to do any more.

When, as, and if a precise seismic survey is available at modest cost, it would be helpful to learn the exact position of the Devils Canyon Fault through our property and its vertical offset of the basement rocks. Presently our few drill holes are widely spaced and we have no information on basement under the State leases when we are slowly drilling Holes A-3 and A-6. Also, we have no information between Holes M-IA and DCA-1A in the north, a distance of nearly 3 miles.

Very truly yours,

Original Signed By
John J. Collins
John J. Collins

cc: RJLacy
WLKurtz

The comments
Attached

RECEIVED
AUG 23 1974
S. W. U. S. EXPL. DIV.

New York, August 21, 1974

MEMORANDUM FOR: Messrs. W. L. Kurtz
C. K. Moss

Superior East, Arizona

Your recent note about Oak Flat caused me to review the file and see Cal Moss' memorandum of June 6, copy attached.

It seems to me our drilling has not established the configuration of the Whitetail Basin since we have no penetration to basement east and south of Hole A-4. The proposed hole south of A-2 may not be in the most advantageous position for several reasons.

Therefore I recommend renewed consideration be given to seismic surveys in Sections 27, 34, 5 and 4 this season. Please comment on accessibility. Mr. Moss should estimate costs.

Thank you.

John J. Collins

Attachment

Notes

SE – JJ Collins.

1. As far as known, Cockshy did not radically improve his seismic spread & techniques during the Superior Oil work, other than he may have used a dual spread for better fault trace evaluation. This dual work has been partially used on Sec. 5 & we have some ~~control~~ evaluation.

2. Cockshy-Sup Oil work west of the town of Superior had less than 500 feet of Tw under similar thickness of Dact & a variable thickness of Gila Cgl & volc cover for a total cover of 2510' in hole #1 to 4000' in hole #2.

It has appeared in the past that, in our project area, the thickness of Tw has been the largest contributor to seismic evaluation problems. Thus it would probably be in order for Mr. Moss & Cockshy to really chat about the problems & see if any scheme can be worked out to place good assurance on interpretation.

Additional control data on basement & possible Devils Canyon fault is now available through Cowell hole KC-1 in Sec. 9 (NW corner) & Newmont's B-5 in Sec. 8 (N Center), as well as Newmont dropping of Kerr-McGee DC-1 in Sec. 16 (NE corner). Hard data is not available on B-5 other than it had a

shallow cover of dacite & the total depth was around 4100 feet. (PERHAPS JOHN CAN ~~SECURE~~ SECURE THE CONTACT DATA IN NY :-)
Kelly's hole might be suspicious in hitting Naco at 2917 and bottoming the hole at 3304 for a thickness of 387 feet in that sequence of our cored slide blocks exceed this thickness. And with DC-1 still in Tw at 3270, 0 miles to the south. Contact data for B-5 would aid this problem.

However, I can come up with a basement & fault configuration from the data available.

What "sequence reasons" does JJC have on the proposed site?

Another consideration would be to case hole A-3 and put the CP-50 on it at the termination of DCA-3A.

Slide blocks:

A-1	1374-1527 pesc+Tgm	=	153'	KC-1 2917-3304 Pn = 387'
	3459-3540 Tgm (cutting)	=	81'	
A-2	3920-4289 Tgm+pesc	=	349'	on BR
A-4	6339-6448 Ma	=	109'	
A-7	3682-3730 Tgn	=	48'	
M-1A	2920-3108 Tgr	=	188'	
	2650-3046 Tgr-pesc	=	396'	on slide
AI-1	3046-3238 pesc-Tgm	=	192	on BR
	987-1710 pedb	=	723'	Tdm top.
AH-5	2996-3332 pedsg+db	=	336'	

AMERICAN SMELTING AND REFINING COMPANY
TUCSON ARIZONA

August 28, 1974

Mr. C. K. Moss
Exploration Services Division
Salt Lake City Office

Superior East Project
Pinal County, Arizona

Dear Cal:

As I discussed with you by phone on Monday, I am enclosing the following maps from our Superior East Project:

1) Claim map
2) Drill hole location map showing rock type intercepts
3) Cross-sections

I am also enclosing Jim Sell's gravity report dated June 6, 1973 which includes specific gravities determined by Chuck Elliott on core samples from Superior East.

I hope this information will help in your critical review of whether seismic surveys can help determine fault planes and premineral bedrock configuration.

Very truly yours,

W. L. Kurtz

WLK:lb
Encs.

cc: JDSell

EXPLORATION SERVICES DIVISION
3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

September 27, 1974

Mr. William Kurtz
Tucson Office

Seismics
Whitetail Basin
Superior East

Dear Bill:

This is written in initiation of a review of the applicability of seismic work to the problem of exploration for mineralization in the Whitetail at Superior East. John Collins requested such reconsideration in recent correspondence.

In order to educate myself on the geologic picture at Superior East, I have undertaken to make structural contour maps for the Whitetail basin. I have used information compiled by Jim Sell, which you recently sent me.

Although I understand that the Whitetail mineralization favors deeper portions of the basin, I am presently not fully aware of your ideas regarding the controls of the mineralization. I am enclosing the structural contour maps which I have made. I hope these will serve as a suitable base on which you may describe your theories. Will you kindly make notes as you feel appropriate, and return copies to me.

A number of drill holes are not shown on the maps; only those holes which show results relevant to the structural data are included. This allows a more ready visualization of areal vacancies in hard information. From my casual study, it would appear that an accurate definition of the Whitetail basin would require a greater density of holes than now exist. This is particularly true where observable faulting would not exert the dominant control for the basin. In the area southward from A-4, the contours for the base of the Whitetail suggest that the faults (RHC and DC) do not exert dominant control, and the axis of the basin may be taking on a southeast direction.

This area is one which John has mentioned for drilling consideration. If there are no objections, I will proceed to obtain cost estimates for seismic coverage of the area.

Everything considered, I believe J. W. Cooksley Co. would be the best contractor for the job, notwithstanding the results of previous work for us.

In relationship to Mr. Cooksley's personal history, I would make the following points:

1) He has had far-and-away the greatest contract experience in seismic work for mining exploration in the Southwest.

2) His previous work for your office was beset with gross misinterpretation of depths, and his delivery time on results was poor. His excuses at the time were poor knowledge of velocity values, and inadequate computer service for his data. Both of these excuses, perhaps, were valid; certainly his work in intervening years should put him in better standing in this regard.

3) On the positive side, Cooksley was the contractor for the work done at Superior, in which the Magma Vein Fault was the target. (Reference A. I. M. E. publication, which was recently circulated.)

I have also made inquiries of two of Cooksley's recent clients, as to his performance, and have received favorable comments.

4) The prime reflecting interface for the work at Superior does not exist in the section at Superior East; however, Cooksley considers the pre-Whitetail erosion surface at Superior East to be an unusually good reflecting interface. He further considers that he can distinguish the pre-mineral crystalline rocks from the pre-mineral sediments where they underlie the Whitetail. A distinction such as this could be important in porphyry possibilities on the project.

5) Cooksley has been conducting work in Globe district in which part of his objective has been to identify alteration zones in concealed intrusive rocks. He contends that alteration effects can be mapped by seismics once a known correlation is established. While this application is more on the speculative level, a spin-off for porphyry exploration could result, in any seismic work at Superior East.

Yours very truly,

Cal Moss

C. K. MOSS

CKM/mb
Enc.

cc: J. J. Collins (w/enc.)
R. J. Lacy "

JDS

AMERICAN SMELTING AND REFINING COMPANY
EXPLORATION DEPARTMENT
120 BROADWAY, NEW YORK, N.Y. 10005

ASARCO

RECEIVED
OCT 3 1974
S. W. U. S. EXPL. DIV.

W. L. K.
OCT 3 1974

JOHN J. COLLINS
DIRECTOR OF EXPLORATION

AIR MAIL

October 1, 1974

Mr. W. L. Kurtz
Southwestern United States Division
Tucson Office

Superior East, Arizona
Seismic Survey

Dear Mr. Kurtz:

I am amazed by the structure contours and isopach pattern on Cal Moss' maps of September 27th. I suppose his reference data are the sections Jim Sell prepared in August 1972, but I wonder if Jim would not draw the plan view of the Whitetail differently from Cal. Ordinarily faults control the contours, and this will ask Jim to draw his version of structure contours and isopachs of the Whitetail conglomerate, with copies to Cal and to me.

I see some data on Cal's maps that are new to me, i.e., holes B-3, B-5, and KC-1 showing relatively shallow depths for the bottom of the Whitetail. Perhaps it is time for Jim to bring his excellent 1972 maps and report up to date? Have our drill holes been surveyed for vertical angle? If not, at least one deep one (probably A-4) should be done as soon as convenient. Please advise what possibilities exist. Also report on the temperature measurements previously requested and comment on ground water quality and quantity in our drill holes. Has Halpenny reviewed this project?

Very truly yours,

John J. Collins

cc: CKMoss

J. D . SELL

EXPLORATION SERVICES DIVISION
3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

October 24, 1974

Mr. J. J. Collins
New York Office

SEISMICS
SUPERIOR EAST, ARIZONA

Dear John:

Mr. James Cooksley recently visited us in relation to the possibility of his doing additional seismic work at Superior East.

I gave him a copy of the tentative coverage which you suggested, in order that he could comment on costs and practicability of coverage.

Cooksley came back with the attached map showing how he would propose to cover the area, considering problems of access and topography. In order to get continuous coverage across Devils Canyon he would shoot from one side while recording on the other. This technique would lose some shallow information, but would probably get the important information from depth.

He suggests that we might enter into the project by first covering only profiles A, A', B and B'. He would propose to do this for $10,000 and would experiment with off-set shooting and other variations in order to determine the most effective procedures. Any additional work could then be considered in the light of this phase.

Subsequent to Cooksley's visit here, he sent me the results of work he did for us earlier in the southernmost part of our ground. The attached sheet shows his contour interpretation for section 4. He considers the profile here to be one of the more reliable of his earlier work. Whether or not his inference is accurate, it is nonetheless interesting that his results also suggest a south-easterly trend in the structure.

My personal evaluation of Cooksley's capabilities in the area would

limit his probable contribution to the determination of coarse aspects of the structural picture. I doubt that he would be able to identify slide blocks, or detail structural breaks. Resolution of features near fault planes would be difficult to accomplish.

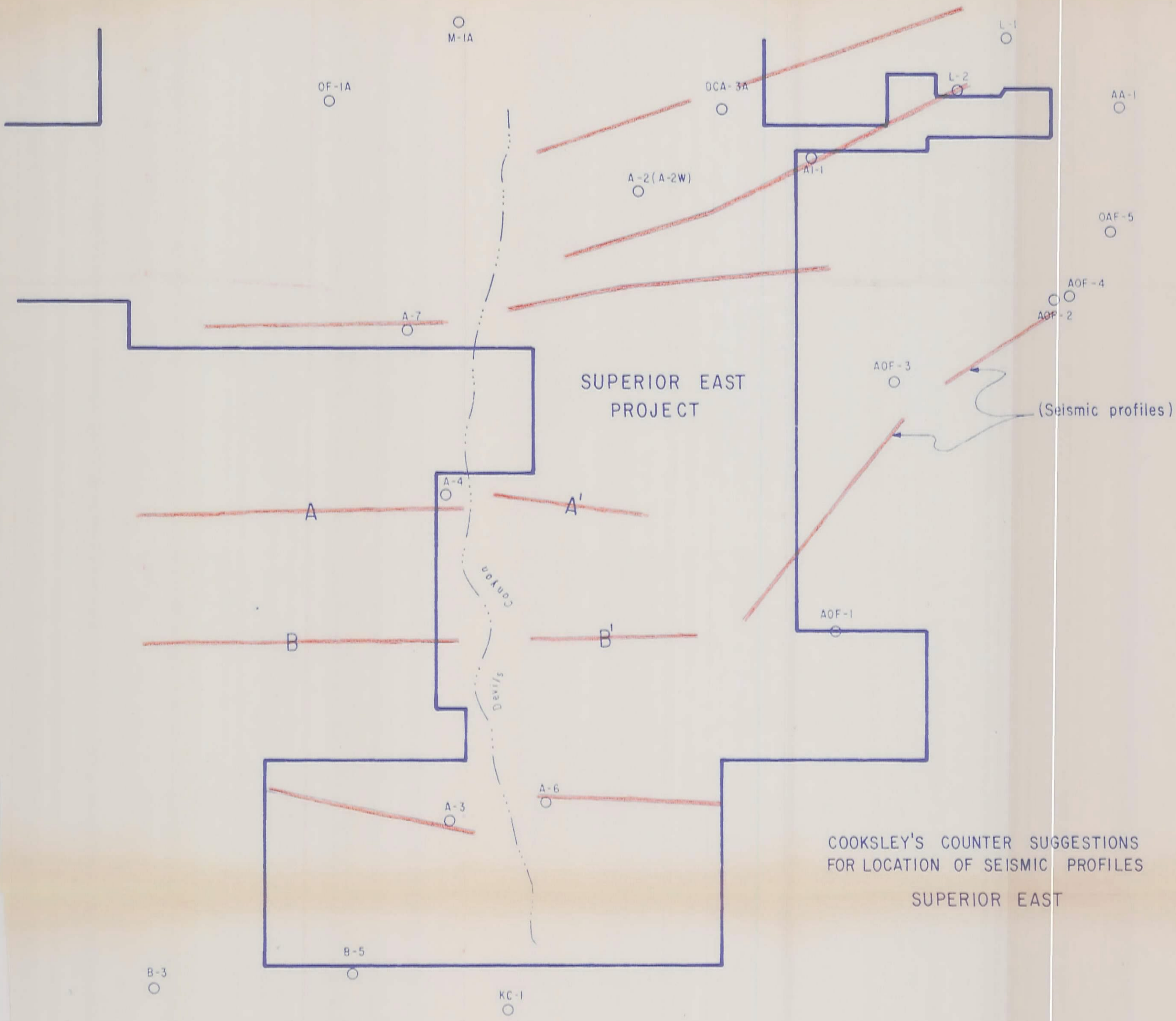
Yours very truly,

C K Moss

C. K. MOSS

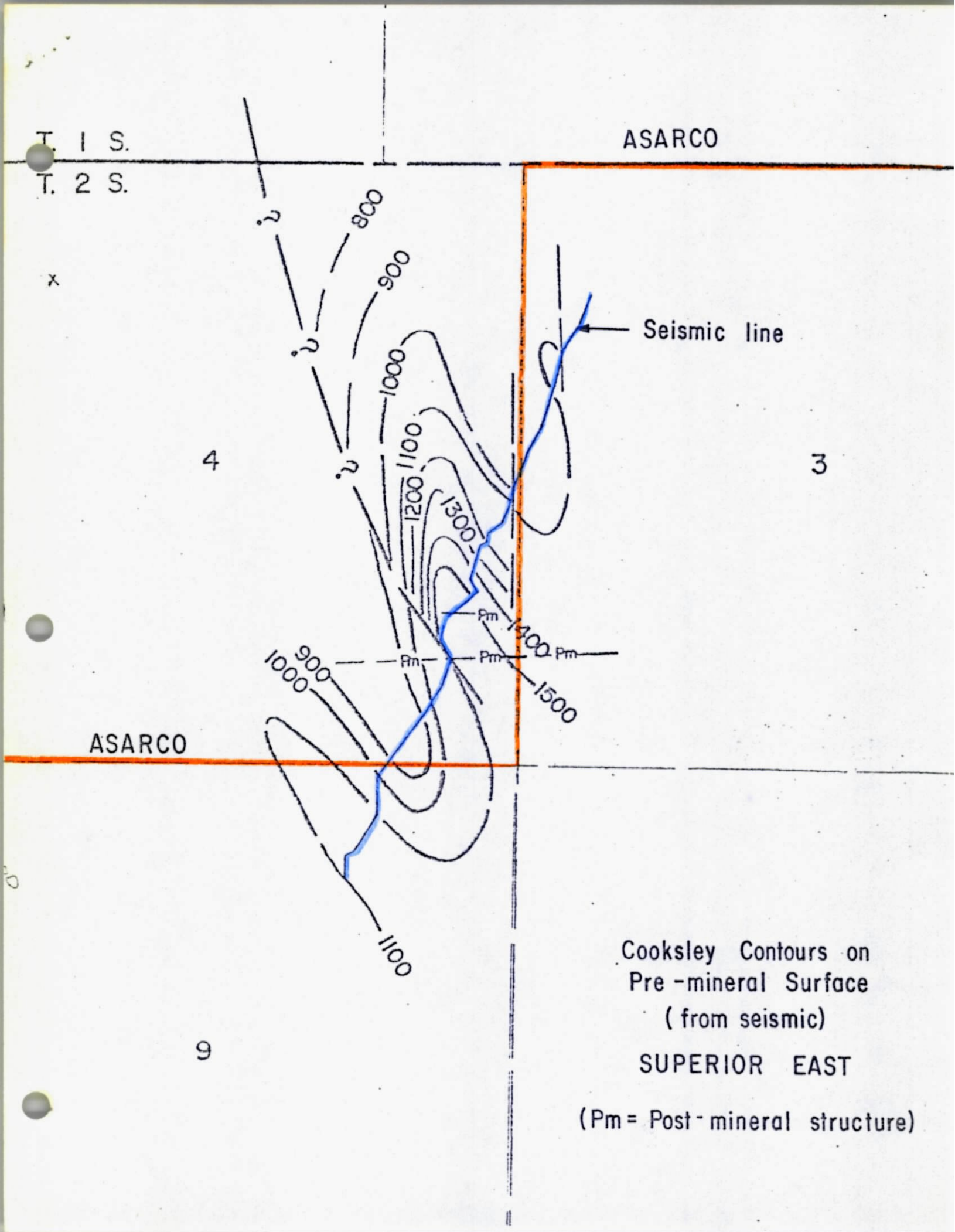
CKM:am
Attch.

cc: W. L. Kurtz, w/enc.
J. D. Sell "
R. J. Lacy "



COOKSLEY'S COUNTER SUGGESTIONS
FOR LOCATION OF SEISMIC PROFILES

SUPERIOR EAST


T. 1 S.
T. 2 S.
ASARCO
ASARCO
Seismic line
4
3
9
800
900
1000
1100
1200
1300
1400
1500
Pm
Pm
Pm
Pm
900
1000
1100
Cooksley Contours on
Pre-mineral Surface
(from seismic)
SUPERIOR EAST
(Pm = Post-mineral structure)

JDS

RECEIVED
NOV 4 1974
S. W. U. S. EXPL. DIV.

W. L. K.
1974

ASARCO

AMERICAN SMELTING AND REFINING COMPANY
EXPLORATION DEPARTMENT
120 BROADWAY, NEW YORK, N.Y. 10005

JOHN J. COLLINS
DIRECTOR OF EXPLORATION

AIR MAIL

October 30, 1974

Mr. C. K. Moss
Exploration Services Division
Salt Lake Office

Seismics
Superior, Arizona

Dear Mr. Moss:

Acknowledging receipt of your letter of October 24, I must ask if Cooksley's plan would not result in averaging the effect of displacement on the Devil's Canyon Fault? This appears to be the case on the map of his previous work where he tries to connect contours across a fault. I would rather see a profile of his work rather than his horizontal interpretation. Please send it. Did he have any drill hole results to anchor his readings?

In the absence of any basement drill hole data on our property east and south of Hole A-4, and not much to the northeast, I must ask if we would not be well served to have a seismic line on each side of the Devil's Canyon Fault and parallel to it? This should indicate the real depths to basement, which is our objective on both sides, as well as the displacement. Your proposed east-west profiles A. A', B. B' would then be more significant. Probably we also need a profile due east from Hole A-7.

Profile E-W ? need two lines NS on one side of canyon to tie and get dip on fault

In view of the above, I suppose Cooksley's cost estimate could go to $20,000 or more if we accept the successive stages. Therefore Mr. Kurtz can put $30,000 in his 1975 budget for seismic surveys. We are approaching the two million dollar mark on this project and need some more extensive knowledge of the Whitetail basin in these several square miles. not really! Need detail which probably will not get from Seismic.

Very truly yours,

John J. Collins

John J. Collins

cc: WLKurtz

AMERICAN SMELTING AND REFINING COMPANY
TUCSON ARIZONA

November 5, 1974

Mr. J. J. Collins
Director of Exploration
New York Office

Seismics
Superior East Project
Arizona

Dear Mr. Collins:

In a letter of June 6, 1974 from Mr. Moss to you, I am quoted: "Mr. Kurtz feels that our drilling to date has fairly well established the general overall configuration of the Whitetail basin and general distribution of the rock types. He feels that additional seismic work would be more of a research project and not directly applicable to guiding further exploration at Superior East."

In a letter of October 24, 1974 from Moss to you, Mr. Moss states: "My personal evaluation of Cooksley's capabilities in the area would limit his probable contribution to the determination of coarse aspects of the structural picture. I doubt that he would be able to identify slide blocks, or detail structural breaks. Resolution of features near fault planes would be difficult to accomplish."

My conclusion of the recent discussions between Kurtz and Moss, Moss and Cooksley, Sell and Cooksley, and Sell and Kurtz is that additional seismic work at Superior East will not materially affect or change our exploration plans at Superior East. The Whitetail conglomerate, with its greatly varying composition and specific gravity, has not yet allowed a constant velocity to be assigned to it and therefore does not allow an accurate calculation of thickness.

In my mind there is no justification of spending 10-20-30,000 dollars on seismic work at this time. The limits of the 0.5% to plus 1.0% native copper have to be defined and this can only be done by drilling. I believe the next exploration step is drilling a hole south of A-4. This could be a new hole 3500' south of A-4 or deepening A-3 (7500' south of A-4).

Very truly yours,

W. L. Kurtz

W. L. Kurtz

WLK:lb

cc: JHCourtright
CKMoss
JDSell

JDS ✓

EXPLORATION SERVICES DIVISION
3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

November 6, 1974

Mr. John Collins
New York Office

SEISMICS
SUPERIOR, ARIZONA

Dear John:

This is in reply to your letter of October 30.

Attached is Cooksley's cross-section interpretation for his seismic profile across section 4, which you requested. The contour map, in plan view, which you commented upon in your letter, certainly has to be considered only as Cooksley's idea of how the areal pre-mineral surface might fit his line of seismic information.

For his work, he did not have drill information on which to anchor depth values, in answer to another question.

Your concern that taking profiles across the faults would result in an averaging effect for depth, I surmise, comes from your experience with refraction seismics. This effect is not a comparable concern in reflection work. Taking the profiles across the faults would on the other hand provide closer control on the location of the faults.

Yours very truly,

Cal

C. K. MOSS

CKM:am
Enc.

cc: W. L. Kurtz, wo/enc.

FROM: W. L. KURTZ

Seismic
11/20, 74

To: JDS

You should be prepared to discuss Cooksley's work on TCO (Pce 2,3) especially specific examples (as you have related to me) where his interp has been wrong and why it may not improve much even with additional drill data.

FROM: W. L. KURTZ

Seismic
11/20, 74

To: JDS

You should be prepared to discuss Cooksley's work on TCO (Pce 2,3) especially specific examples (as you have related to me) where his interp has been wrong and why it may not improve much even with additional drill data.

Sup East
11/22, 74

FROM: W. L. KURTZ

TO: JHC
JDS

11/22 call from TCO

he says Director of Exploration-
says seismic survey will be
run and charged to
Superior East.

TCO's opinion is that no
reason to be boss if you
can't ~~mu~~ pronounce there
-edits once in a while.
Will check whether we have to
hold off on A-3.

cpy for JDS ✓ BH JAC, FTG

AMERICAN SMELTING AND REFINING COMPANY
EXPLORATION DEPARTMENT
120 BROADWAY, NEW YORK, N.Y. 10005

JOHN J. COLLINS
DIRECTOR OF EXPLORATION

AIR MAIL

November 20, 1974

Mr. C. K. Moss
Exploration Services Division
Salt Lake Office

Superior East, Arizona
Seismics

Dear Mr. Moss:

On reading your memo of November 8 to me and Mr. Kurtz's letter of November 5 to me, I appreciate his comments but I see that there is a fundamental misunderstanding.

I am the one who wants seismic profiles across our Superior East basin through probable or possible future drill sites but anchored to the facts of our existing drill holes. The primary purpose is to determine if Cooksley can indicate the varying depths to basement.

In addition I understand from previous correspondence that Cooksley may be able to distinguish different kinds of basement rocks which, if true, would be significant in spotting holes for a porphyry copper. If he can recognize the top of the Whitetail, that would be helpful too, but not a prerequisite.

Accordingly, please prepare and send me a formal request for an appropriation of funds to cover four east-west lines, but arrange with Cooksley that his contract would be two for sure and two more at our option. In our previous talks, I have proposed E-W lines through Holes A-7 (4 miles) and A-4 (4 miles). Kurtz's November 5 letter mentions two more drill sites, which would be the optional lines, amounting to about 7 miles, total 15 miles.

We have been considering the Superior East budget. These charges are to be included in it.

Cooksley's contract will need a confidentiality clause. I will ask Mr. Desvaux to send you a form.

I am going to Manila November 22, but will be back December 1. Will your request be ready for the December 4 Advisory Committee meeting?

Very truly yours,

John J. Collins

John J. Collins

AMERICAN SMELTING AND REFINING COMPANY
TUCSON ARIZONA

December 11, 1974

Mr. T. C. Osborne
ASARCO
New York Office

Seismics
Superior East Project
Pinal County, Arizona

Enclosed are two reports by Cooksley, one dated June 1970 done for Continental Copper and one dated February 1972 done for Asarco.

The two critical items are the selection of the "correct" velocity and the selection of the "correct" reflecting surfaces. An inspection of Appendix C and Appendix B casts serious doubt on accurate selections (Moss, March 27, 1972, sums this subject up quite well).

W. L. Kurtz
W. L. Kurtz

WLK:lb
Encs.

cc: JHCourtright
JDSell
CKMoss

AMERICAN SMELTING AND REFINING COMPANY
TUCSON ARIZONA

November 27, 1974

TO: W. L. Kurtz

FROM: J. D. Sell

Seismics
Superior East Project
Pinal County, Arizona

Attached is a table showing the various depths to bedrock which J. W. Cooksley has submitted during various studies made on the Superior East Project area.

Actual drill hole information has also been added, and the difference between the seismic and drill hole information is provided; also, a note on the unit which occupies the depth of his reported seismic reflection.

The drill holes which have an indented number (such as A-2) show several different depths suggested by Cooksley, as the data has been refined or depth given to him for velocity comparison. As noted, a general decrease in actual error was appreciated as more information became available.

Two basic questions still are unresolved: 1) the velocity to be used in computations, and 2) is the event which is picked the true surface named?

James D. Sell
James D. Sell

JDS:lb
Attach.

TABLE 1. Reflecting Surface Depth Estimates of J. W. Cooksley Compared to Actual Drill Hole Depths.

Hole Number	Collar Elevation	Depth to Top of Whitetail Below Collar	Depth to Top of Whitetail Sealevel Elevation	Depth to Top of Bedrock Below Collar	Depth to Top of Bedrock Sealevel Elevation	Indicated Seismic Depth to Reflecting Surface Below Collar	Indicated Seismic Depth to Reflecting Surface Sealevel Elevation	Difference Between Seismic and Actual DDH Information	Actual Unit Recorded by Seismic
A-1	4720	1527	+3193	1566	+3154	1520	+3200 (1)	+ 7'	Just above top of Tw in slide block of schist.
A-2	4340	2020	+2320	3920	+ 420	3165	+1175 (1)	+ 755'	Middle of Tw. (755' above base.)
A-2 (5)						3720 (5)	+ 620 (5)	+ 200'	Lower 1/4 of Tw. (200' above base.)
A-3	4125	1430	+2695	below 1949	below +2176	3125	+1000 (2)	?	
A-3 (6)				4525	- 400 (6)	3125	+1000 (2)	+1400' (?)	?Middle of Tw (1400' above base)?? EST. to base of Tw.
A-4	4100	2133	+1967	6484	-2384	2700	+1400 (1)	+3784'	Upper 1/4 of Tw.
A-4 (2)						4130	- 300 (2)	+2084'	Middle of Tw.
A-4 (4)						5680	-1580 (4)	+ 804'	Lower 1/4 of Tw. (Approx. depth given to JWC for comparative purposes.)
A-6	4120	1475	+2645	below 1665	below +2455	No info.	No Info.	—	—
A-7	4210	2445	+1765	5610	-1400	2535	+1675 (1)	+3075'	100' below top of Tw.
M-1A	4500	2428	+2072	4998	- 498	2400	+2100 (1)	+2598'	Top of Tw.
M-1A (4)						4850	- 350 (4)	+ 148'	148' above base in Tw. (Depth supplied to JWC for comparative purposes.)
AI-1	4625	2250	+2375	3073	+1552	2625	+2000 (1)	+ 448'	Middle of Tw.
AOF-1	4240	1106	+3134	2939	+1301	2340	+1900 (1)	+ 599'	Lower 1/4 of Tw.
AOF-1 (4)						3070	+1170 (4)	- 131'	131' below base of Tw. (Depth supplied to JWC for comparative purposes.)
AOF-1 (2)						2940	+1300 (2)	- 1'	1' below base of Tw. (Depth supplied to JWC for comparative purposes.)
DCA-1A	4760	2210	+2550	4669	+ 91	No info.	No info. (1)	—	—
DCA-2A	4780	1415	+3365	1452	+3328	1780	+3000 (1)	- 328'	328' below base of Tw. (JWC had access to depth.)
DCA-3A	4640	2430	+2210	4454	+ 186	3140	+1500 (1)	+1314'	Middle of Tw.
DCA-3A (3)						3500	+1140 (3)	+ 954'	Lower 1/3 of Tw.
OF-1A	4420	below 2150	below +2270	below 2150	below +2270	2520	+1900 (1)	—	Depth to base of Tw unknown.
KC-1	3960	1010	+2950	2917	+1043	No info.	No info.	—	Depth to base of Tw unknown.
CE-1	4475	below 2850	below +1625	below 2850	below +1625	1675	+2800 (1)	—	Hole information is questionable, but suggests up in Td.
CE-1 (2)						1375	+3100 (2)	—	Hole information is questionable, but suggests up in Td.
C-2	4480	below 1027	below +3453	below 2850	below +3453	1430	+3050 (1)	—	Up in Td unit.
C-2 (2)						1230	+3250 (2)	—	Up in Td unit.

Notes:

(1) Reflecting surface taken from map of 1970 submitted to Continental Copper. JWC had access to depth data from holes OF-1A and DCA-series.
(2) Reflecting surface taken from map of 1971 submitted to ASARCO with new data and interpretation. JWC had access to data from holes M-1A, AOF-1, and A-4.
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(4) From JWC report "Comparison of Seismic Exploration Results with Data on Three Deep Drill Holes", p. 8, to ASARCO dated Feb. 1972. JWC had data from M-1A, AOF-1, and A-4.
(5) Verbal interpretation by JWC on 2/7/72. (Hole A-2 had been completed to 4000' at this date.)
(6) JDS projection to bedrock on 11/8/74 for hole A-3.

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A-3	4125	1430	+2695	below 1949	below +2176	3125	+1000 (2)	?	
A-3 (6)				4525	- 400 (6)	3125	+1000 (2)	+1400' (?)	?Middle of Tw (1400' above base)??
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(6) JDS projection to bedrock on 11/8/74 for hole A-3.

line 1.

Hole	Actual ~~depth~~ elevation of BR	JWC Diff.		Depth of hole known by JWC
DCA-2A	+3328	-328	below base of Tw.	(Depth known).
A-1	+3154	+7	base of Tw	
AI-1	+1552	+448	Middle of Tw	
AOF-1	+1301	+599	Lower 1/4 of Tw	(Depth known)
A-2	+402	+755	Middle of Tw	
DCA-3A	+186	+1314	Middle of Tw	(Minimum depth known).
M-1A	-498	+2598	Top of Tw	
A-7	-1400	+3075	Near top of Tw	
A-4	-2384	+3784	Upper 1/4 of Tw.	

~~line 2~~

E

Table Characteristic Comparison

	Strongest	Moderate	Weakest
Capping			
Amt of Deformation (Type)	A-2 (Strong Catacletic)	DCA-3A (Moderate Catacletic)	AI-1 (Open Breccia)
Amt of Leaching	A-2	AI-1	DCA-3A
Bedrock			
Amt of Alteration (Type)	A-2		
Amt of Solubility (Type)			
Amt of Porosity (Type)			
Amt of Fluid Diffusion (Type)			

Same drafts on each side.

Scale: 1 inch = 1,000 feet

CONTOUR INTERVAL = 100 FEET
DATUM IS SEA LEVEL

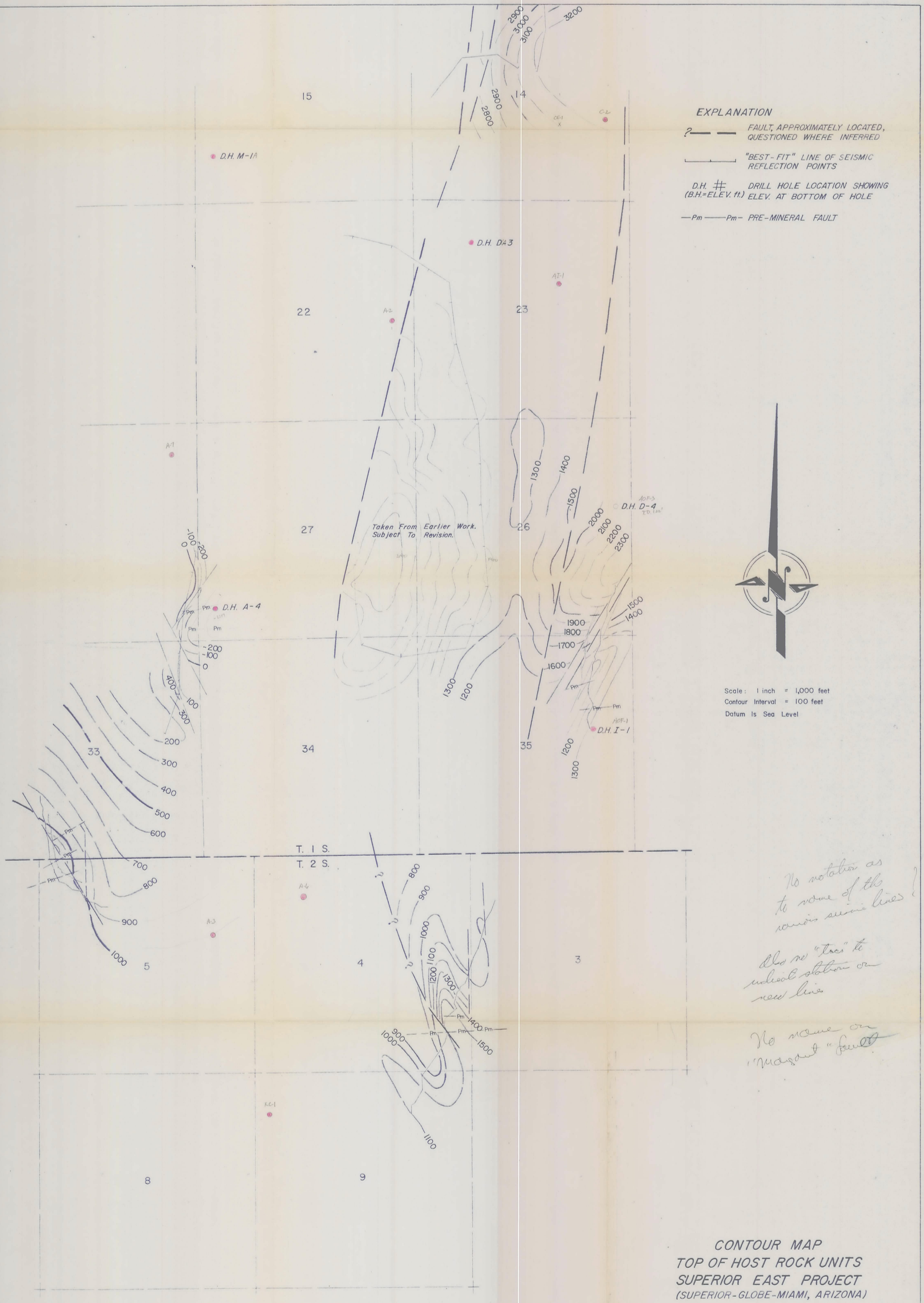
CONTOUR MAP
TOP OF HOST ROCK UNITS
MARGARET CLAIM-GROUP
(SUPERIOR-GLOBE-MIAMI, ARIZONA)

CONTINENTAL COPPER INC.
TUCSON, ARIZONA

GEOPHYSICAL SURVEY CONDUCTED BY:
J. W. COOKSLEY, JR. --- JAN., 1970

Drafted By: W. J. Gray

PLATE I



No notation as to name of the various seismic lines?

Also no "ties" to nearest stations or new lines

No name on "marginal" fault

CONTOUR MAP
TOP OF HOST ROCK UNITS
SUPERIOR EAST PROJECT
(SUPERIOR-GLOBE-MIAMI, ARIZONA)

ASARCO
TUCSON, ARIZONA

GEOPHYSICAL SURVEY CONDUCTED BY:
J. W. COOKSLEY, JR.---MAY, 1971

EXPLANATION OF SYMBOLS USED ON SEISMIC TRAVERSE PLOTS
SUPERIOR EAST PROJECT

o — — o — — o — — o SEISMIC TRAVERSE

—·—·——·—·——·—·— LINE OF REFLECTION POINTS

• SHOT POINTS

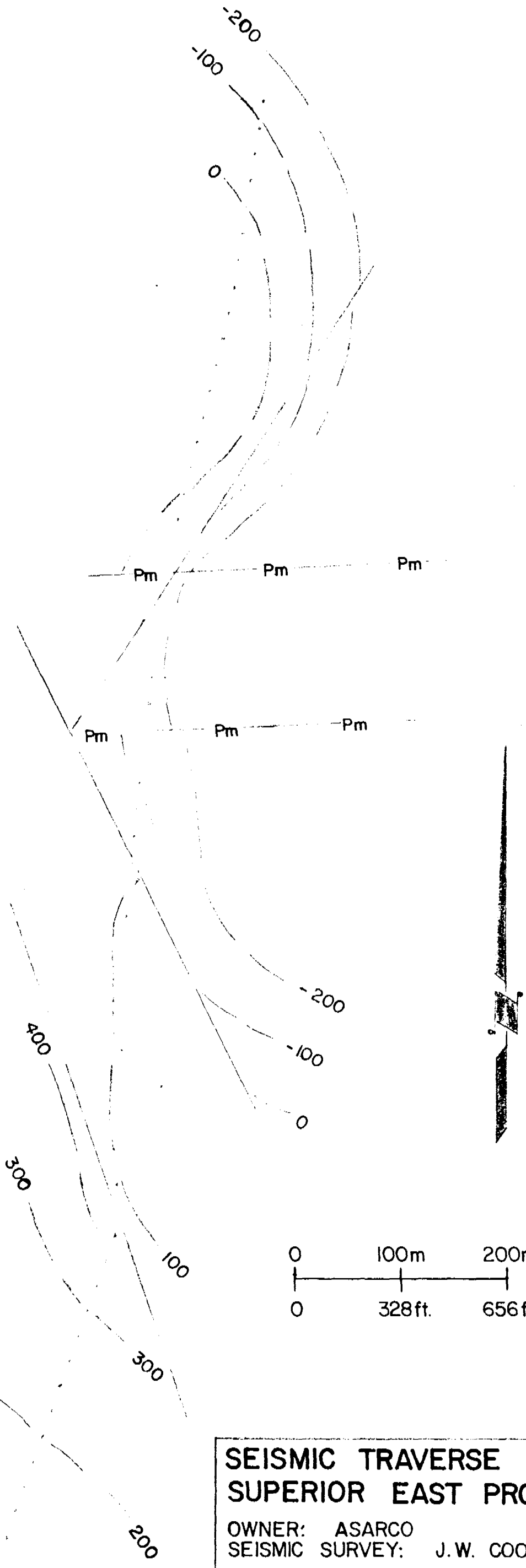
——— ——— ——— FAULT

———Pm———Pm——— PRE-MINERAL FAULT

SECTION LINES

SCALES (ALL TRAVERSE PLOTS):
1 inch = 100 meters ≐ 328 feet

CONTOUR INTERVAL: 100 feet

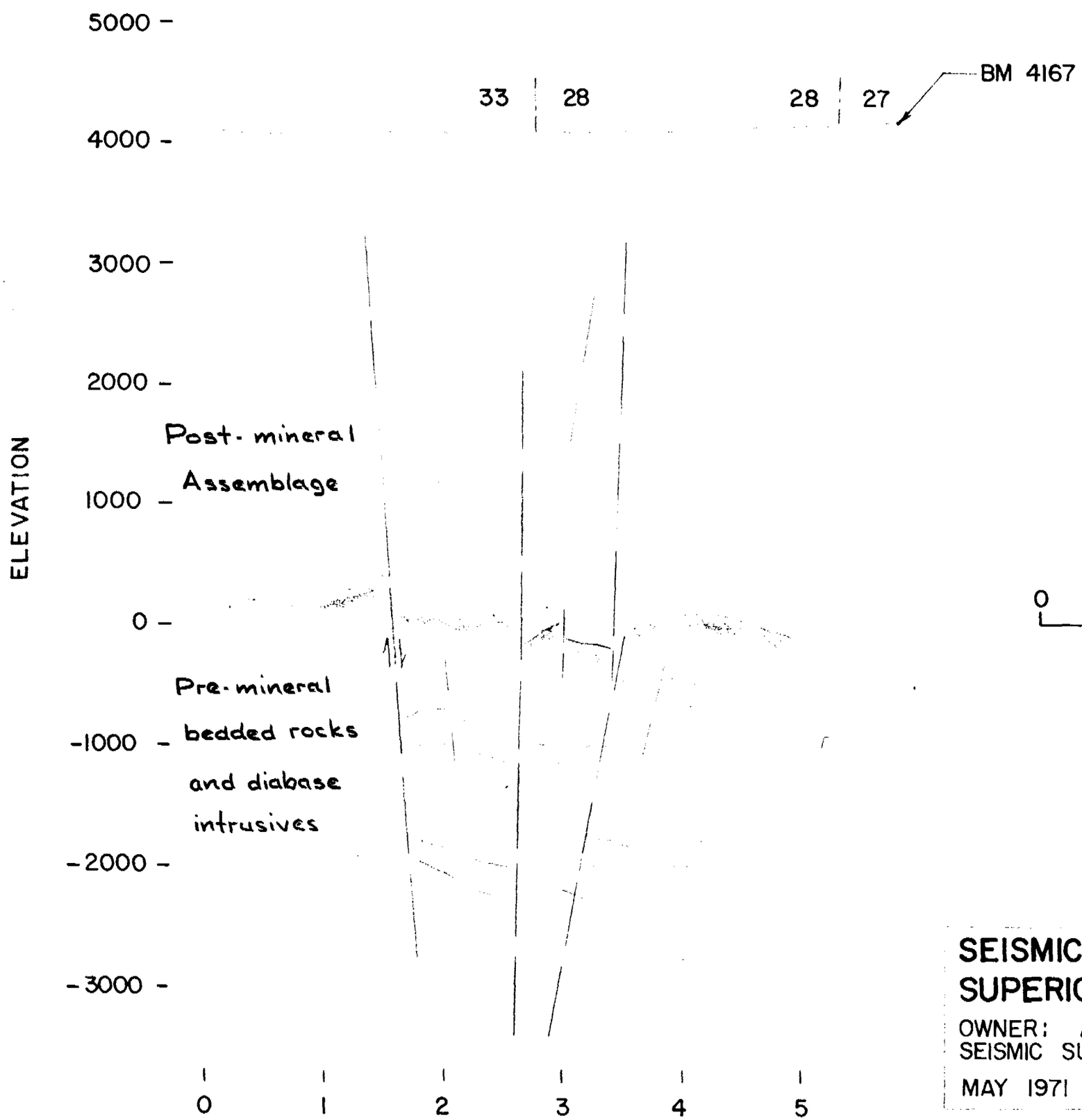


Station number

SEISMIC TRAVERSE C-C
SUPERIOR EAST PROJECT

OWNER: ASARCO
SEISMIC SURVEY: J.W. COOKSLEY

MAY 1971



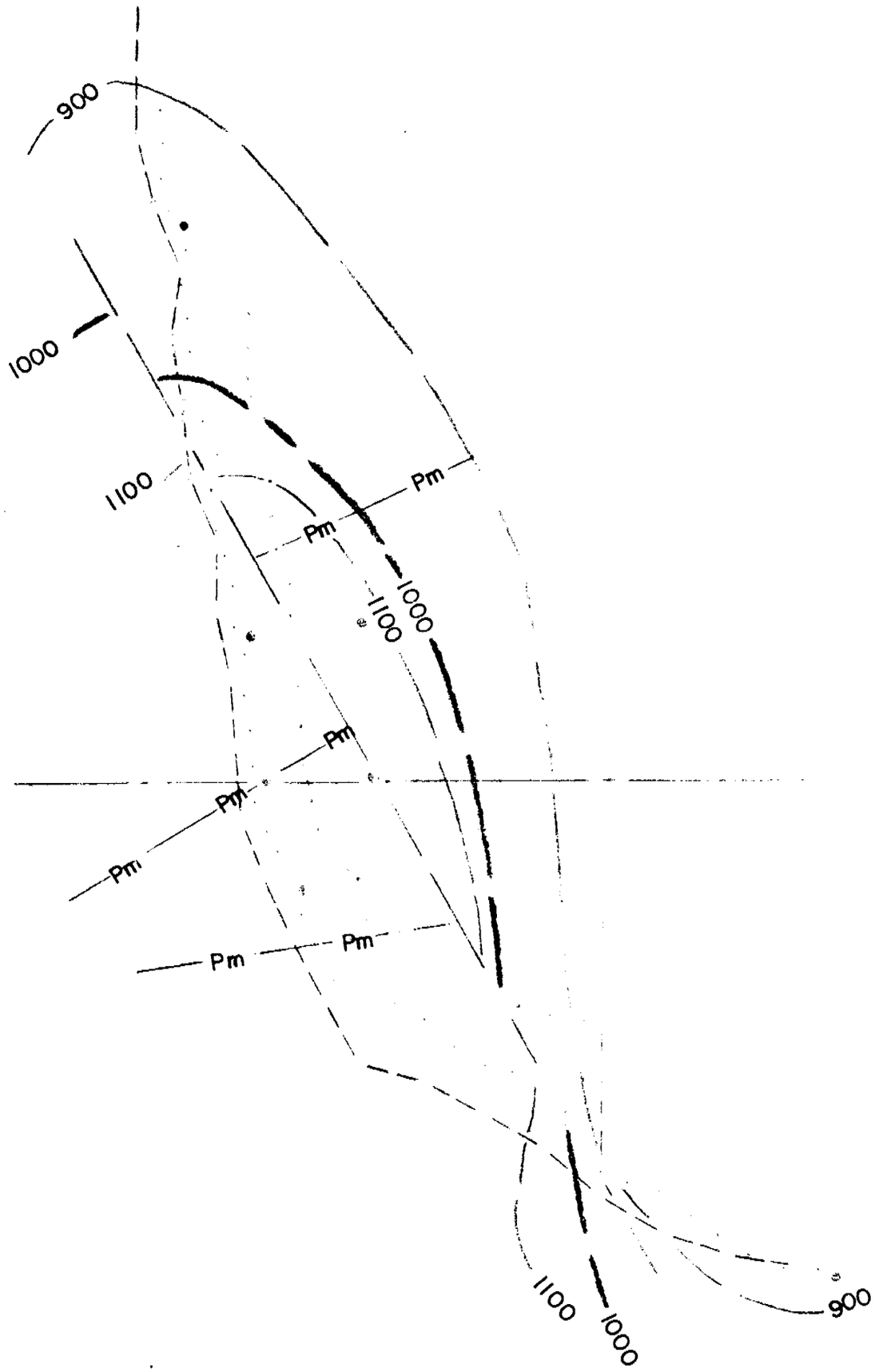
0 1000ft. 2000ft.
Scale

No notation on which way up are looking

SEISMIC SECTION C-C'
SUPERIOR EAST PROJECT

OWNER: ASARCO
SEISMIC SURVEY: J.W. COOKSLEY

MAY 1971



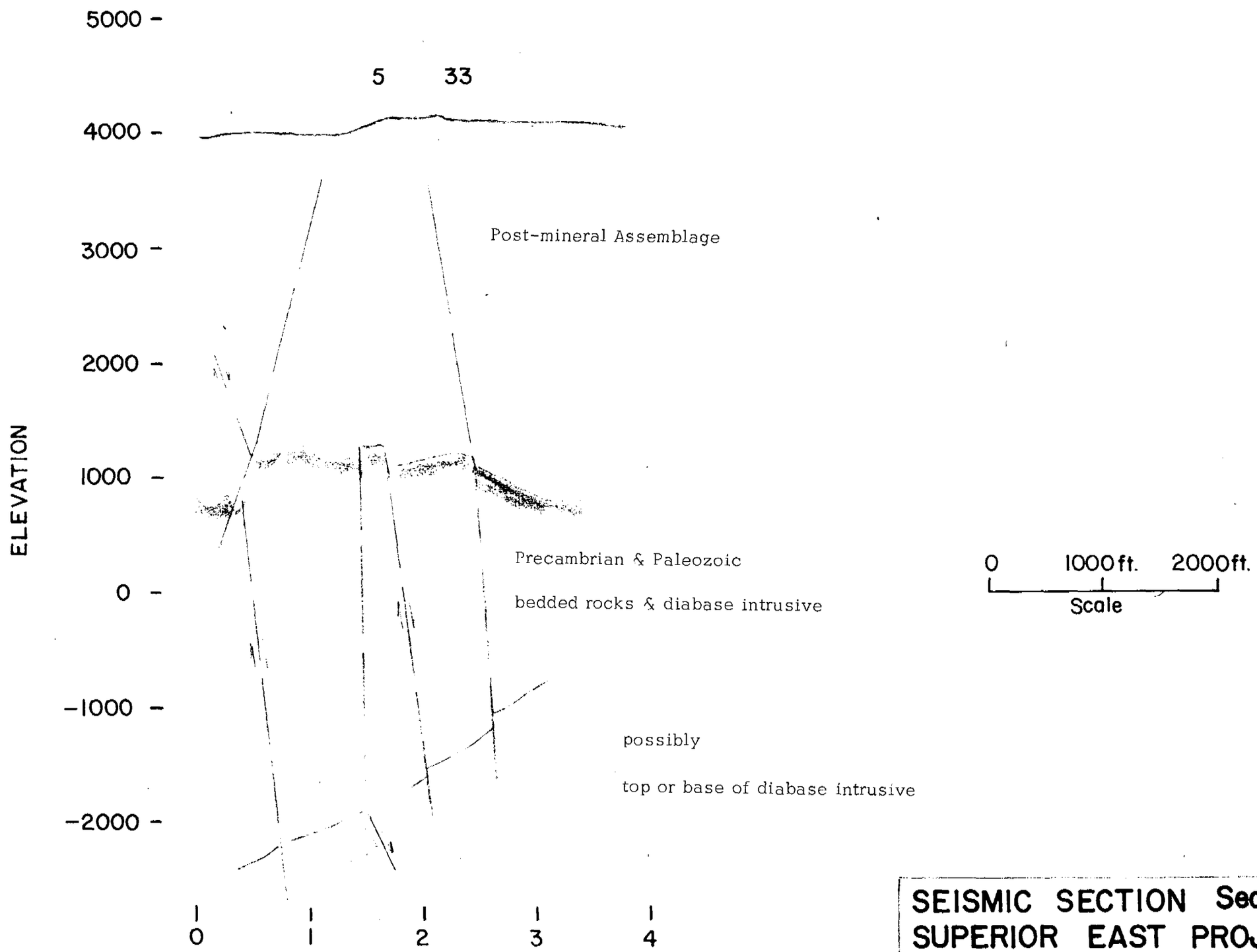
0 100m 200m

0 328ft. 656ft.

SEISMIC TRAVERSE Sec. 5
SUPERIOR EAST PROJECT

OWNER: ASARCO
SEISMIC SURVEY: J.W. COOKSLEY

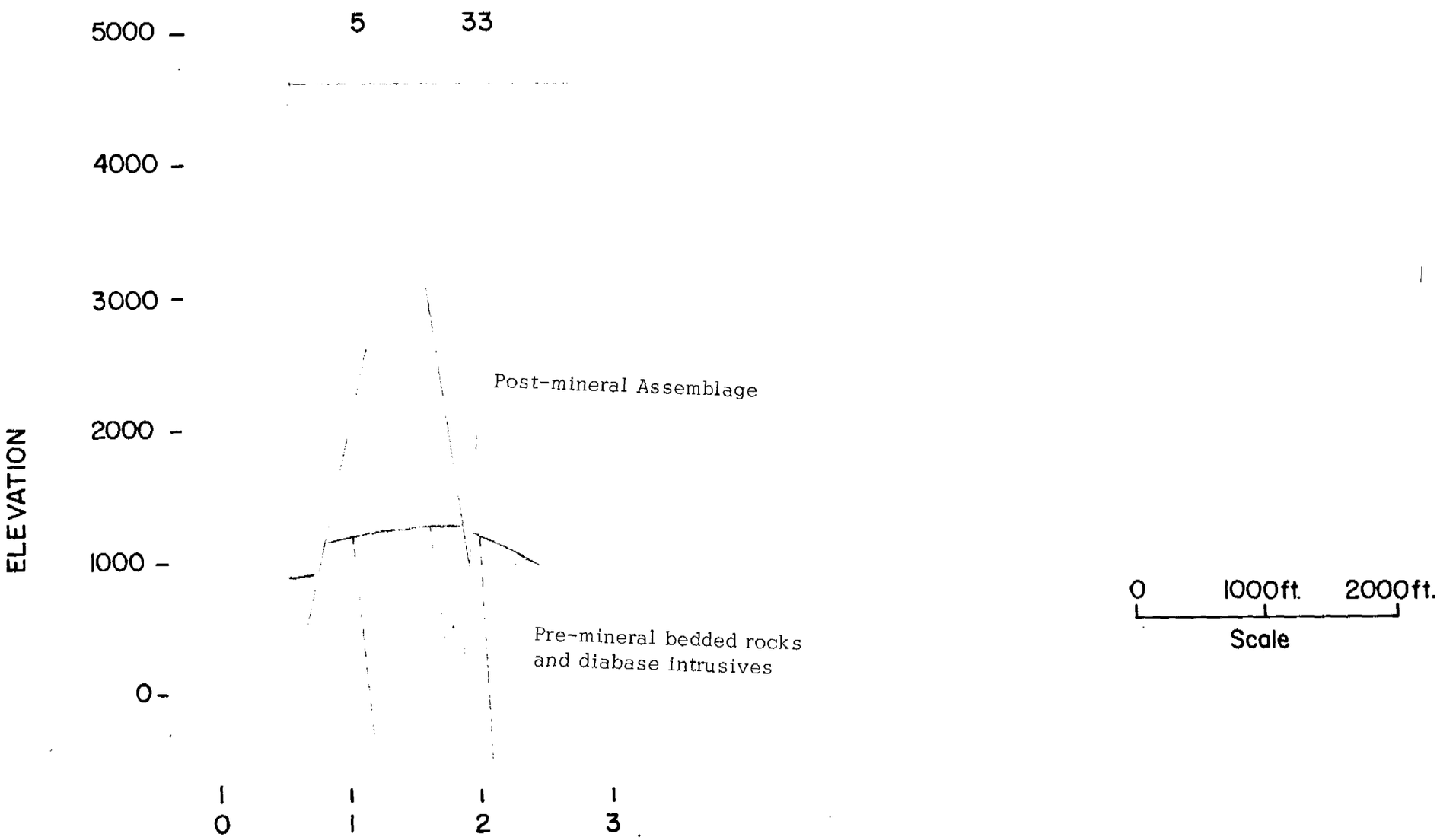
MAY 1971



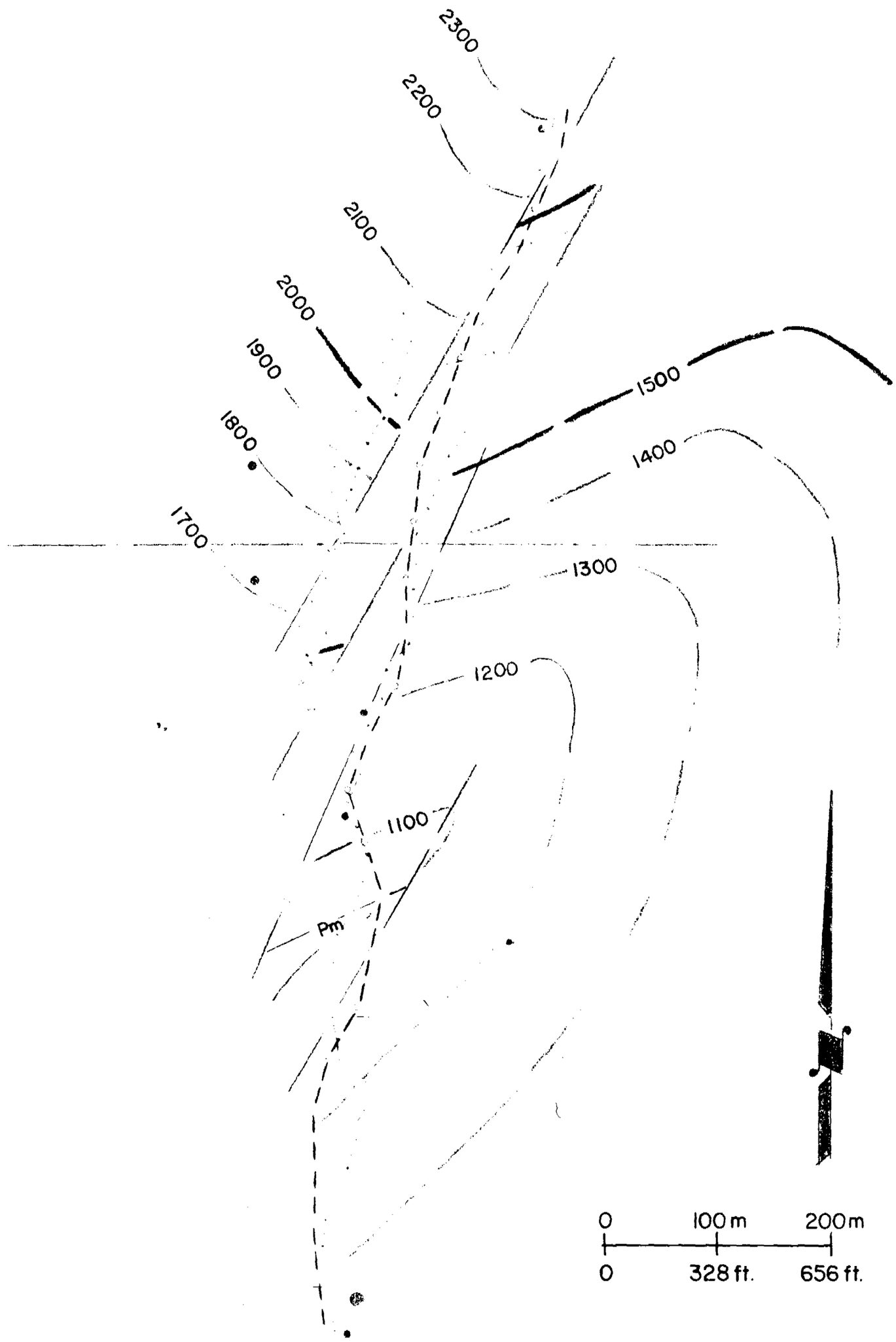
SEISMIC SECTION Sec. 5
SUPERIOR EAST PROJECT

OWNER: ASARCO
SEISMIC SURVEY: J. W. COOKSLEY

MAY 1971



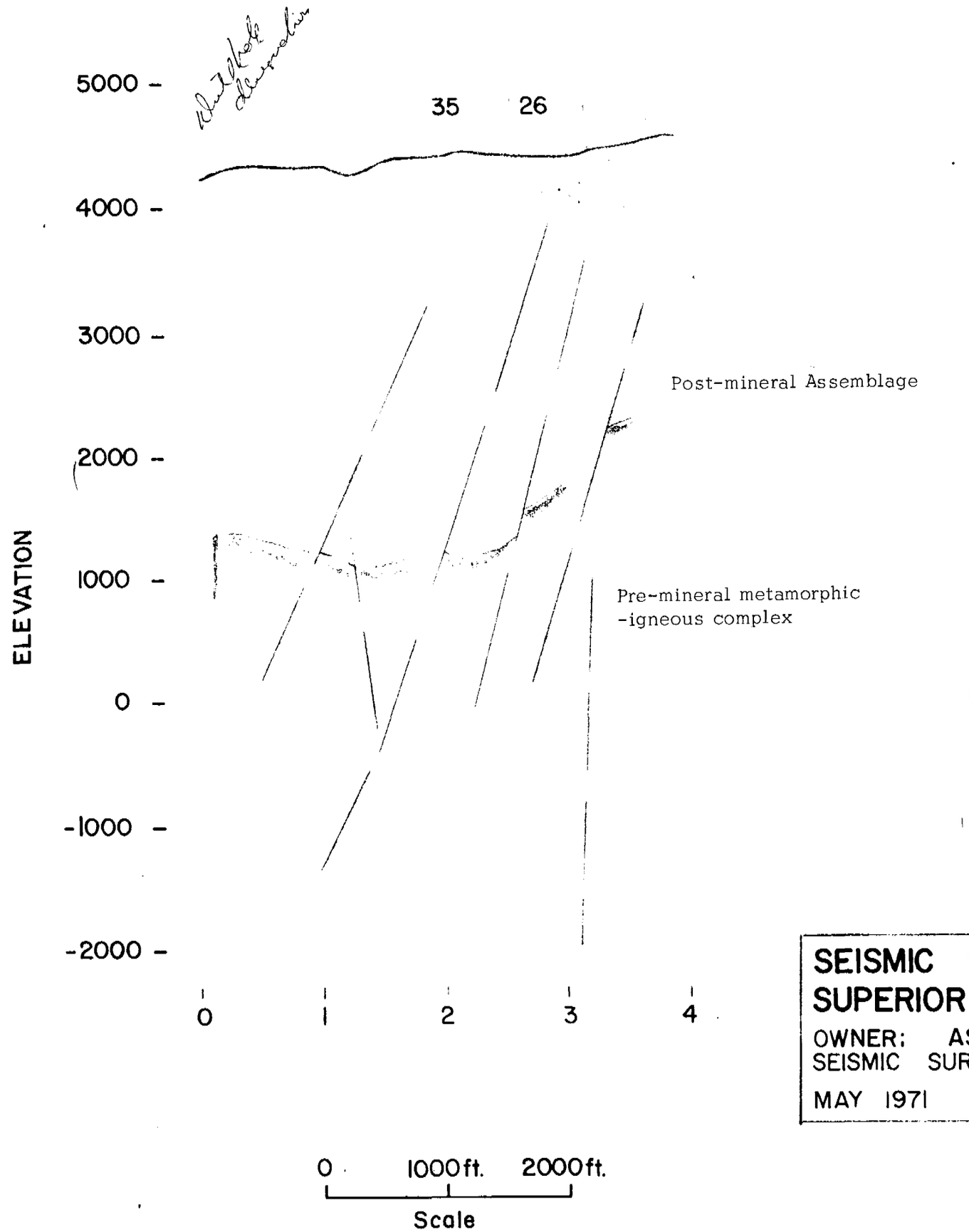
SEISMIC SECTION Sec. 5a
SUPERIOR EAST PROJECT
OWNER: ASARCO
SEISMIC SURVEY: J.W. COOKSLEY
MAY 1971



SEISMIC TRAVERSE I-1
SUPERIOR EAST PROJECT

OWNER: ASARCO
SEISMIC SURVEY: J.W. COOKSLEY

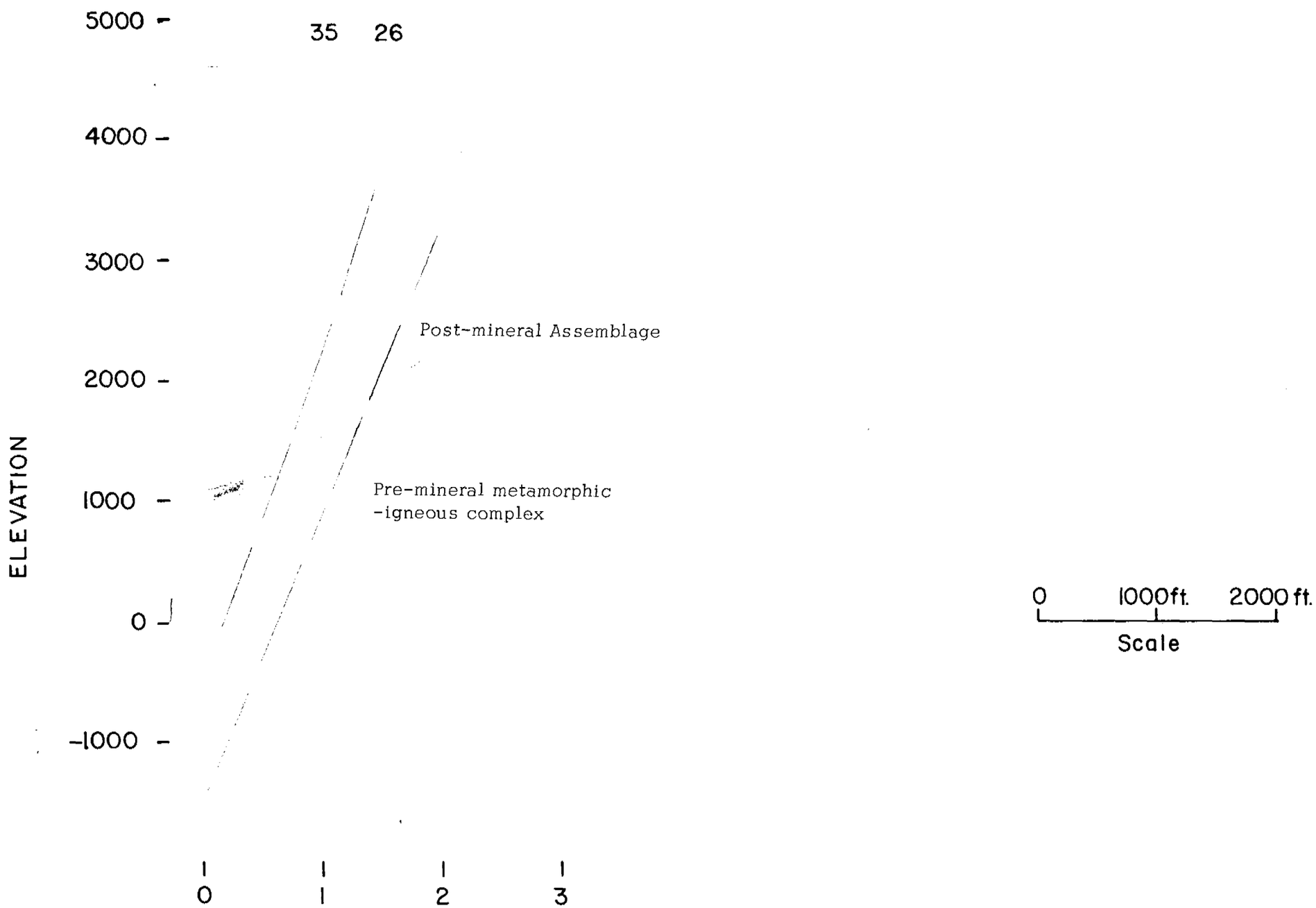
MAY 1971



SEISMIC SECTION I-I
SUPERIOR EAST PROJECT

OWNER: ASARCO
SEISMIC SURVEY: J.W. COOKSLEY

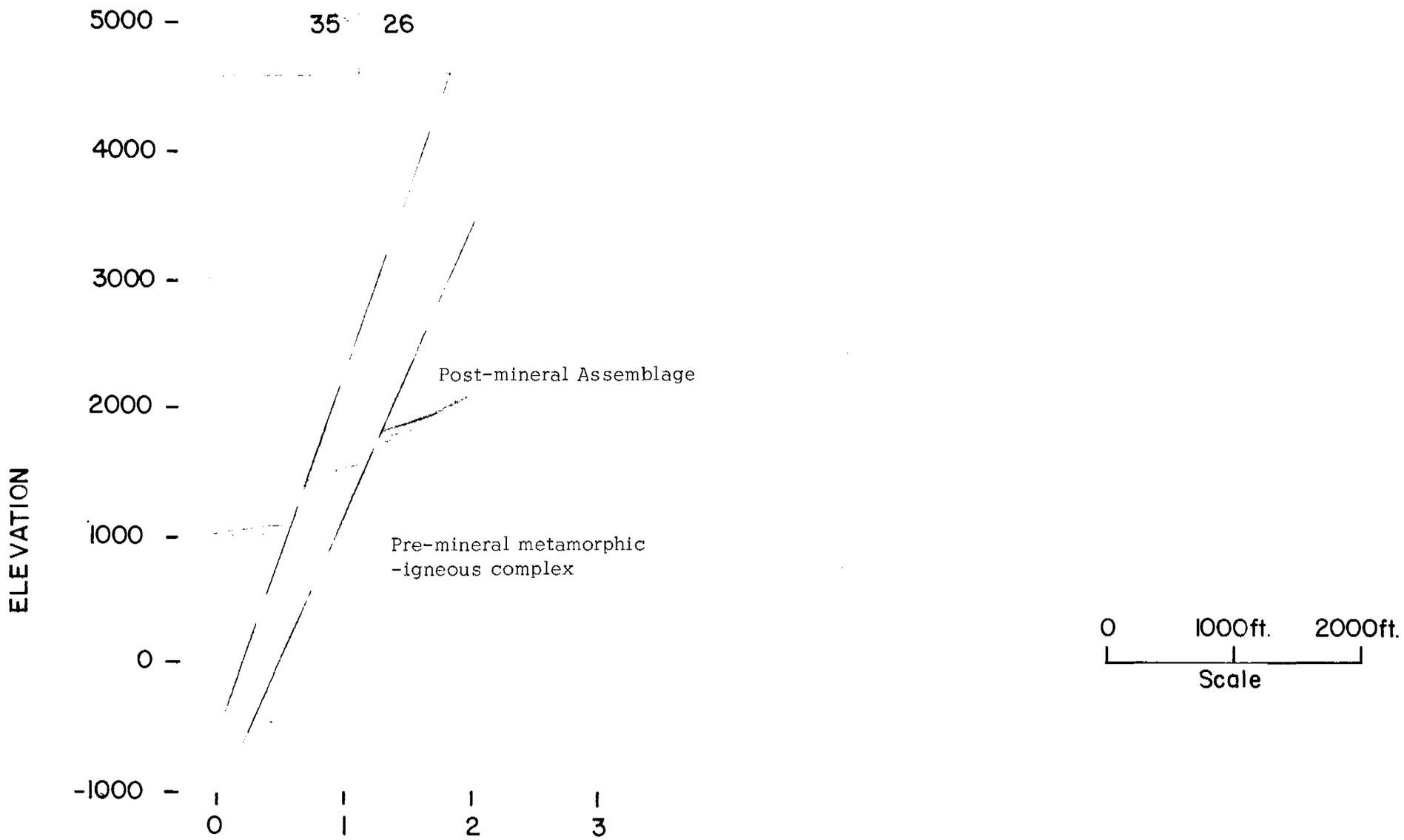
MAY 1971



SEISMIC SECTION I - Ia
SUPERIOR EAST PROJECT

OWNER: ASARCO
SEISMIC SURVEY: J.W. COOKSLEY

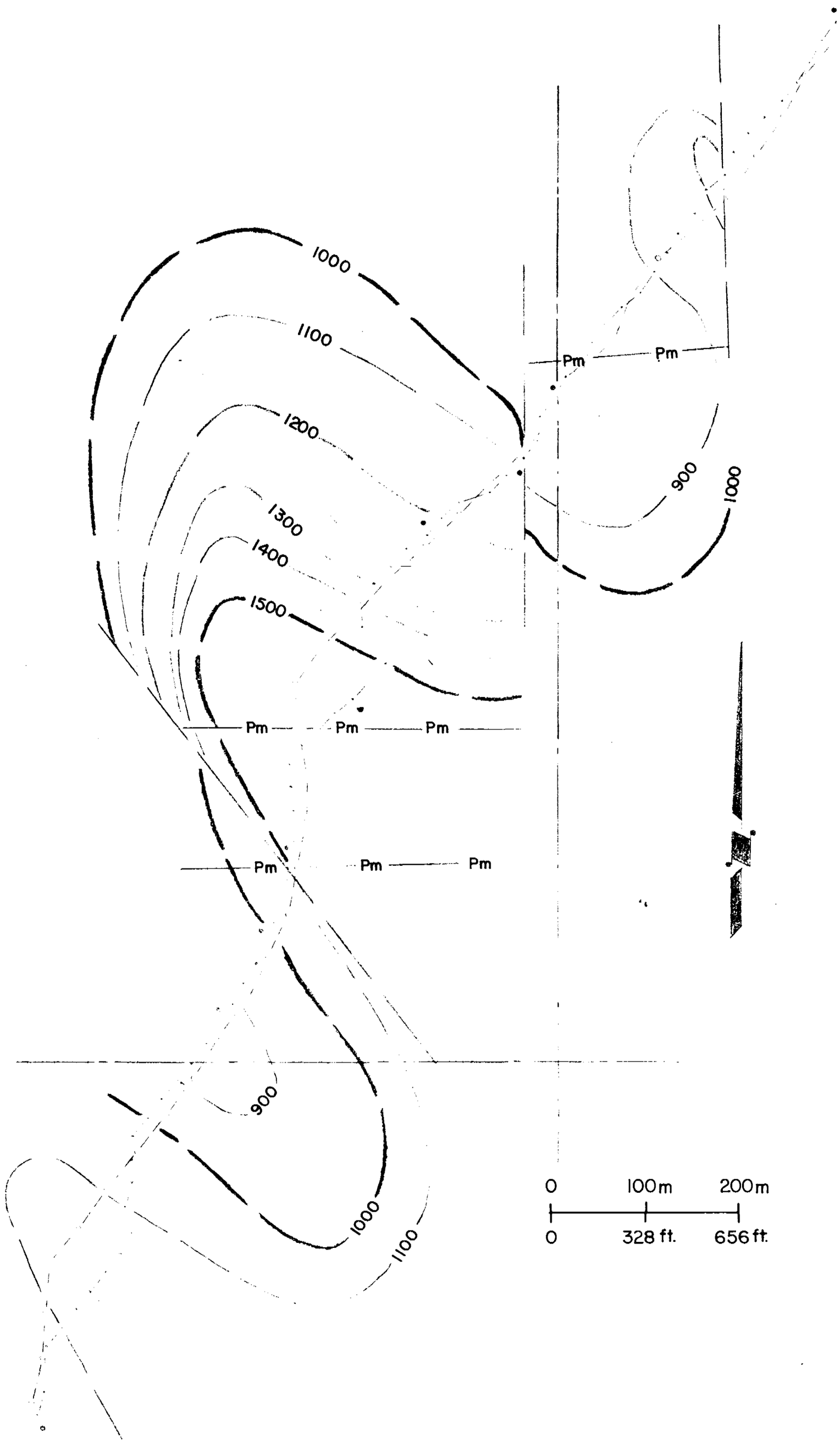
MAY 1971



SEISMIC SECTION I - 1b
SUPERIOR EAST PROJECT

OWNER: ASARCO
SEISMIC SURVEY: J.W. COOKSLEY

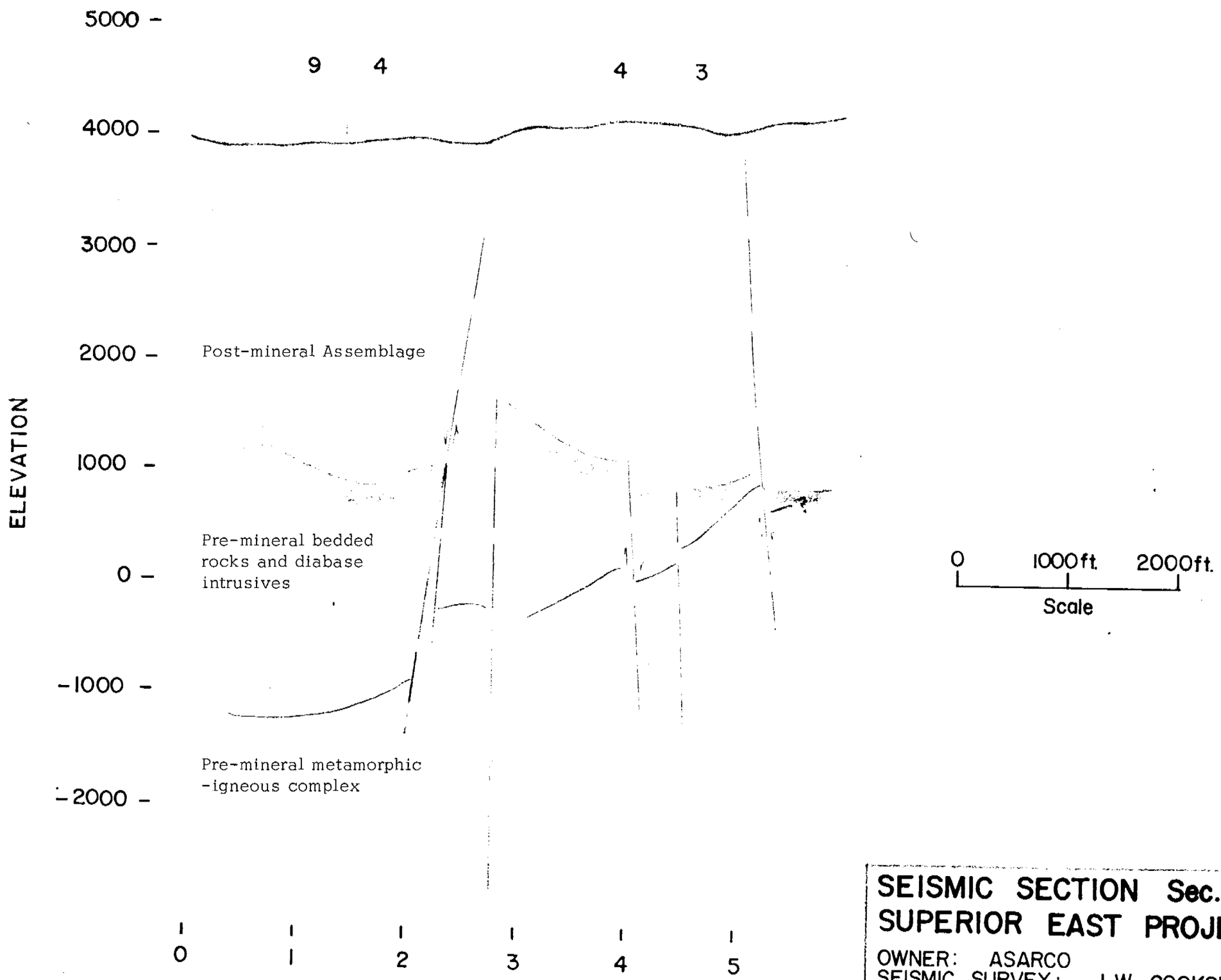
MAY 1971



SEISMIC TRAVERSE Sec. 4
SUPERIOR EAST PROJECT

OWNER: ASARCO
SEISMIC SURVEY: J. W. COOKSLEY

MAY 1971

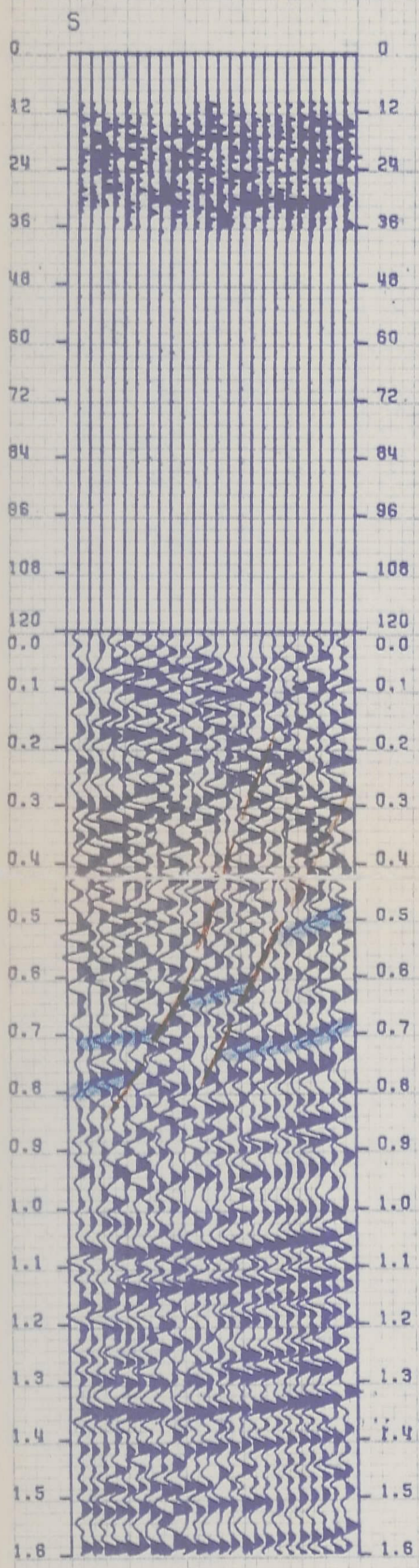


SEISMIC SECTION Sec. 4
SUPERIOR EAST PROJECT

OWNER: ASARCO
SEISMIC SURVEY: J.W. COOKSLEY

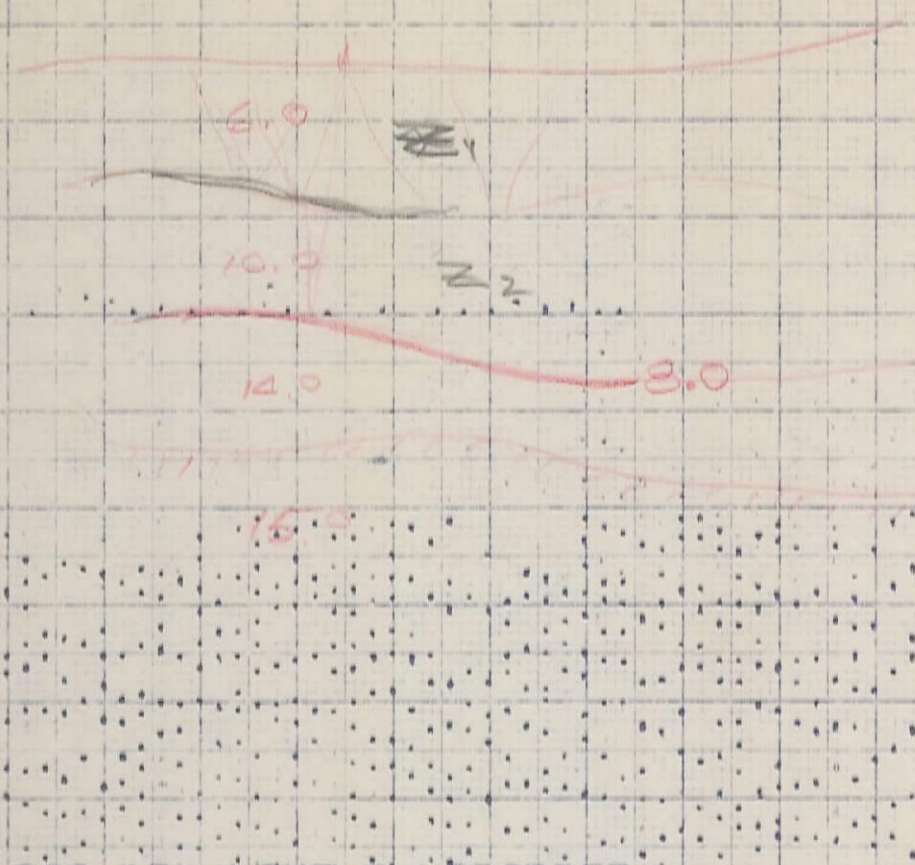
MAY 1971

LINE - 209(I-1) - SP. 6



J.W. COOKSLEY

PROCESSED BY
GENERAL ATRONICS CORPORATION
A SUBSIDIARY OF THE MAGNAVOX COMPANY

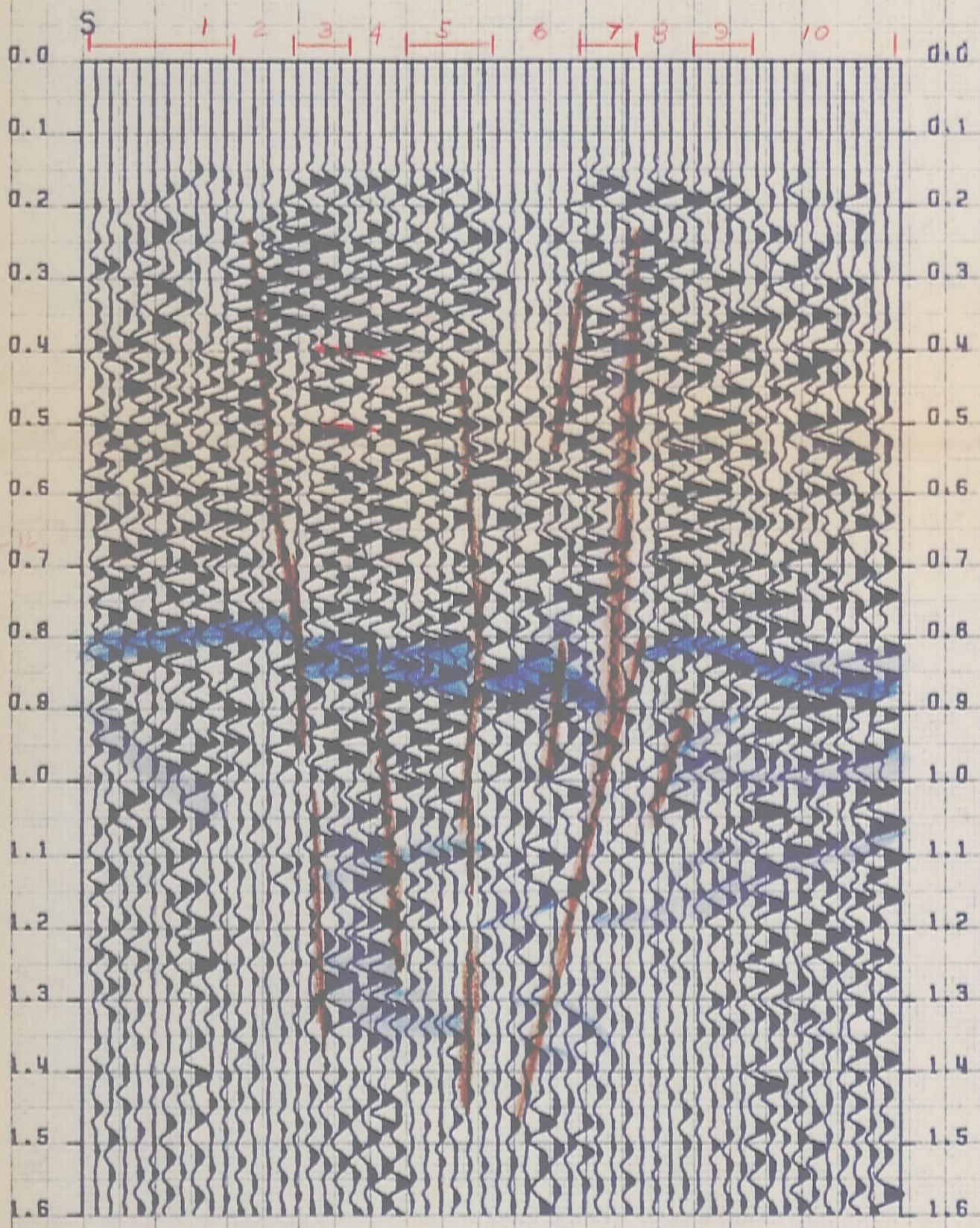


2

$X_{1ms} \times V = D_1$ CLIENT COPY Z_1 compdir

$X_{2ms} \times V_2 = D_2$ $Z_2 = D_2 - D_1$

JOB 209-174 LINE C MARGARET



Fault designed by not shown by color on this sheet.

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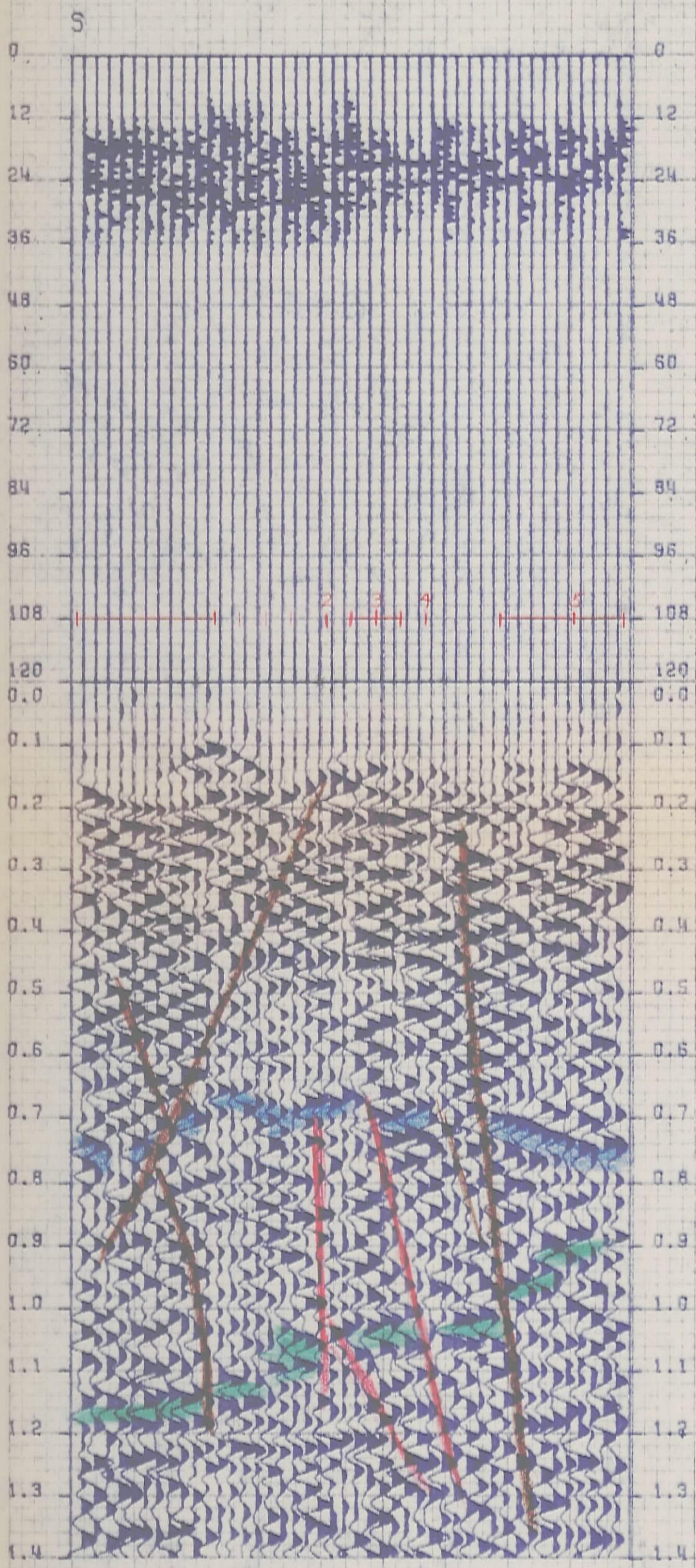
Need rotation as to N-S direction, looking west, etc.

LINE - 209 (SP 1-5)



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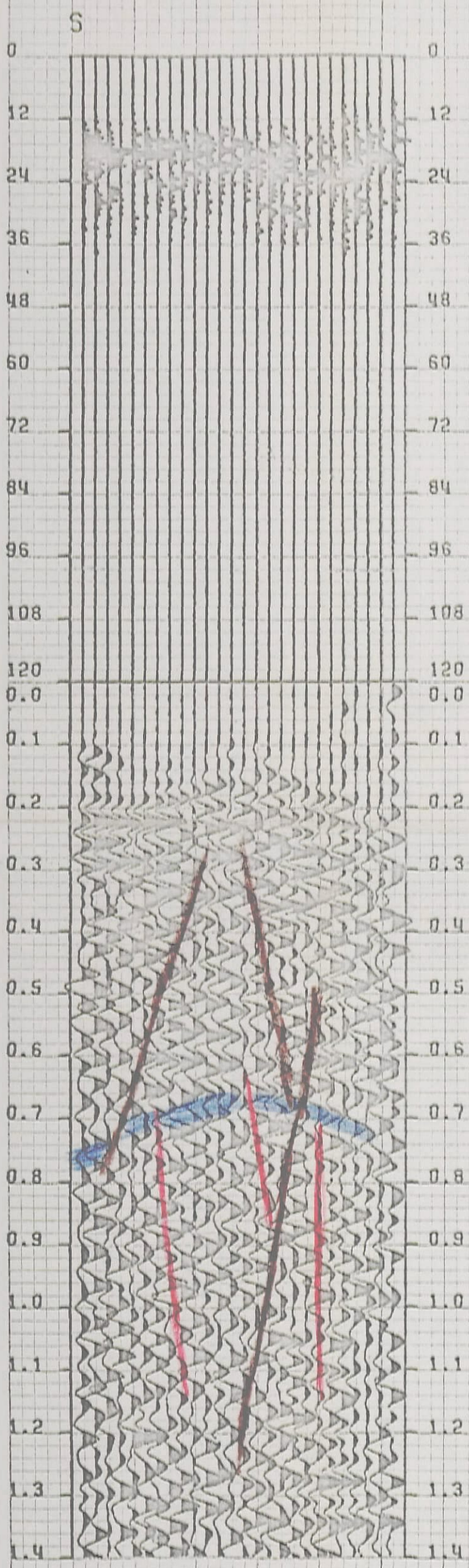
LINE - 209 (SP 6-7)



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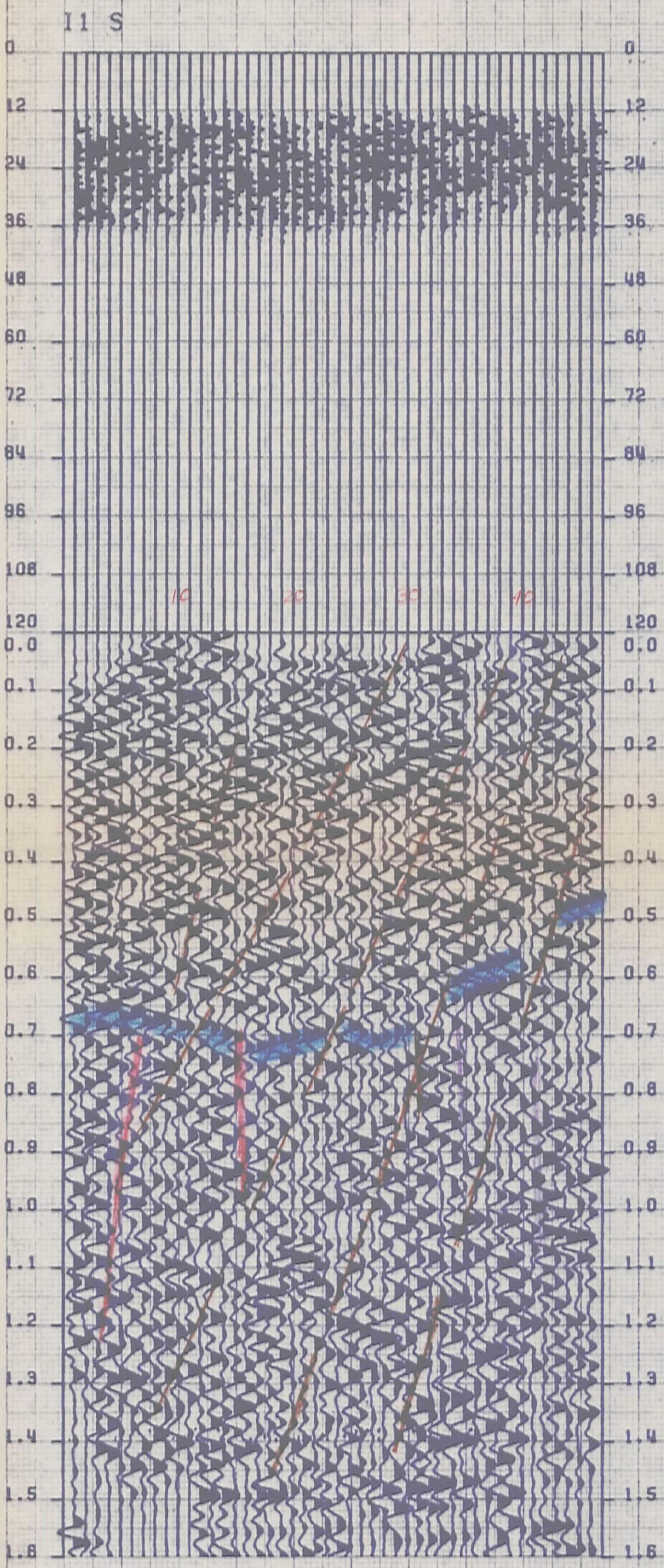
JOB 209 LINES 2(I-1) & 3(SEC 4)



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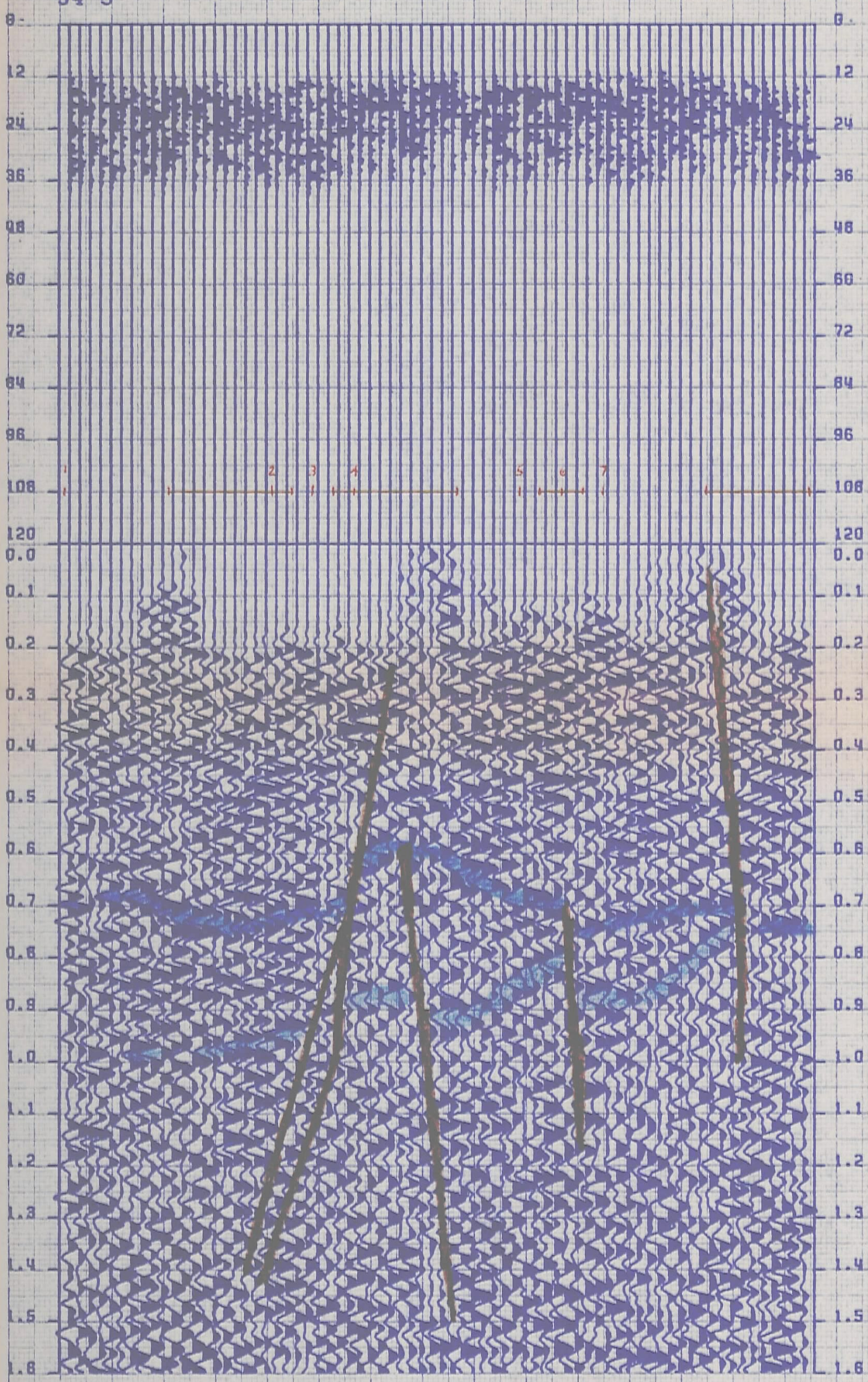
JOB 209 LINES 2(I-1) & 3(SEC 4)

CLIENT COPY



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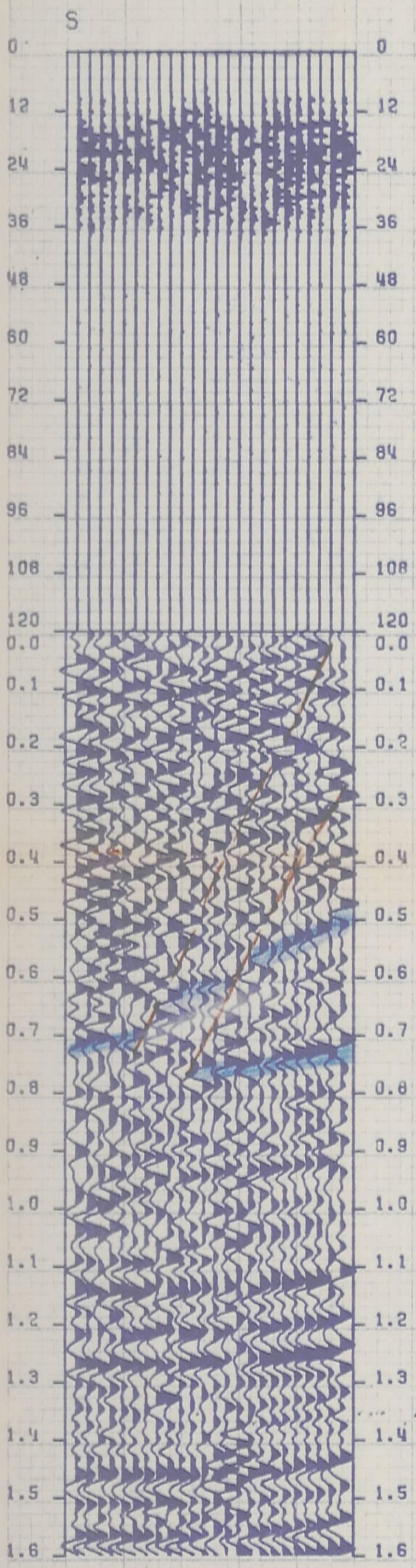
LINE - 209(I-1) - SP' 7



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J. W. Cooksley Company
P.O. Box 1602
Redding, California 96001

2610 East Grant Road
Tucson, Arizona 85716

1974

Derivation of Seismic Sections

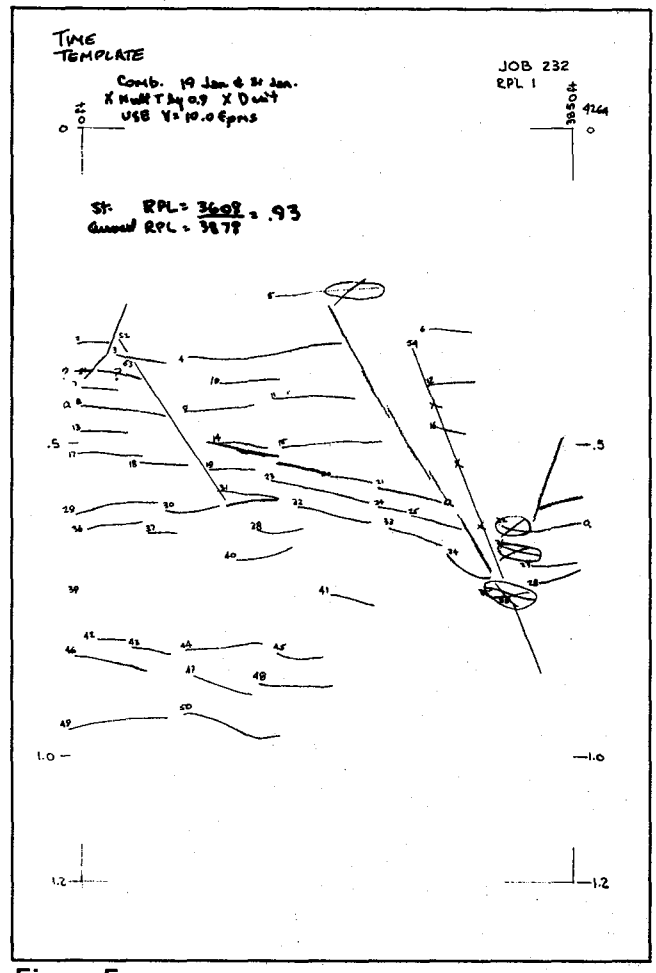


Figure 5

Figs. 1 & 2. Shots L and M are seismic records obtained directly from the field recordings. The wavy lines, each one the reading of an individual sensor, represent both refraction and reflection events. A well-defined event, such as the reflection event indicated by the arrows, appears as a wave of greater amplitude that is coincident from one sensor line to the next. The information obtained from such records primarily involves times, frequencies, and amplitudes of both refracted and reflected arrivals.

Lack of planar reflecting surfaces complicates seismic event interpretation. Simple, two-dimensional, planar reflection horizons are not normally encountered in mining exploration problems. More typical are structural complexity, irregular intrusions, alteration or weathering of old erosional surfaces, and erratic deposition and erosion of Tertiary conglomerates and/or volcanic flows—all of which can cause difficulties in interpretation of events. These problems, of course, are not unique to seismic methods but are inherent in any mining exploration problem. They can be minimized by judicious interpretation of all available geologic information and geophysical data. Thus, attempting to relate a particular seismic discontinuity to a specific geologic feature is a matter of interpretation, and the identifications cannot be stated with certainty without directly correlatable geologic observations, such as drill logs preferably with downhole velocity data. Without such supporting observations, the seismic interpretations should be considered subject to revision in the light of more direct geologic control.

Seismic exploration programs can be directed to measuring the thickness of post-mineral alluvial and volcanic deposits, delineating fault and fold structures, observing the dip of stratified rock units, detecting the presence of intrusives, and interpreting the presence of alteration and fracturing.

Figs. 6 & 7. The seismic profile of Fig. 5 is now converted to digitized form (Fig. 6). In Fig. 7, it has been taken a step further and subjected to thorough geologic interpretation and revision. It should be noted that a time-depth factor has been applied, giving fairly accurate depths to the discontinuities revealed in the seismic cross sections.

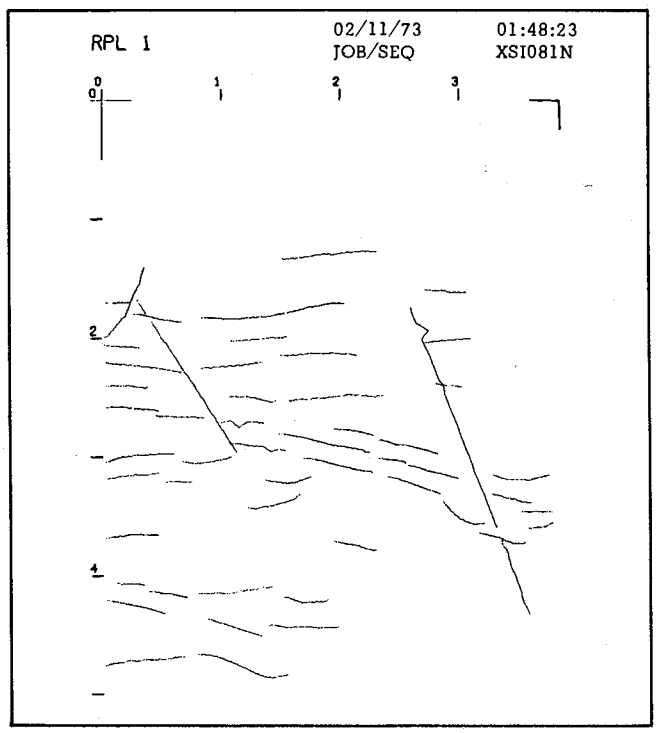


Figure 6

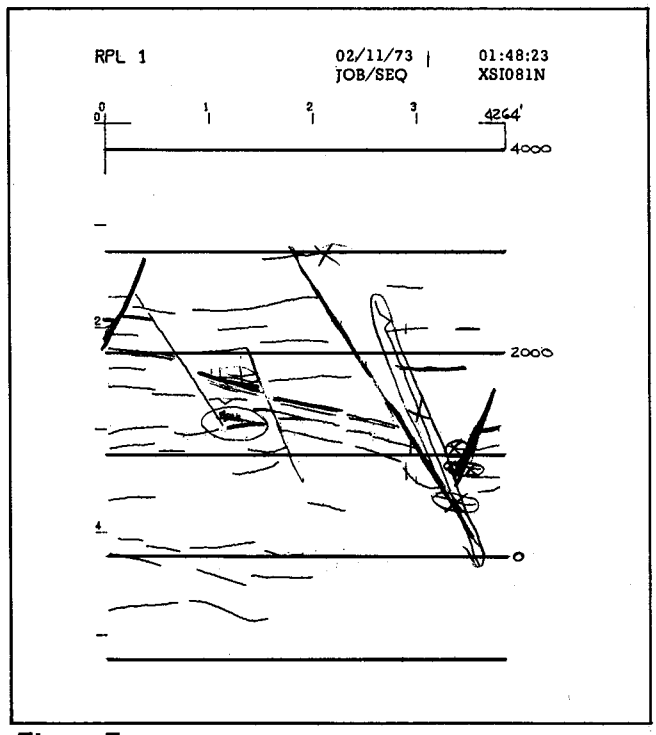


Figure 7

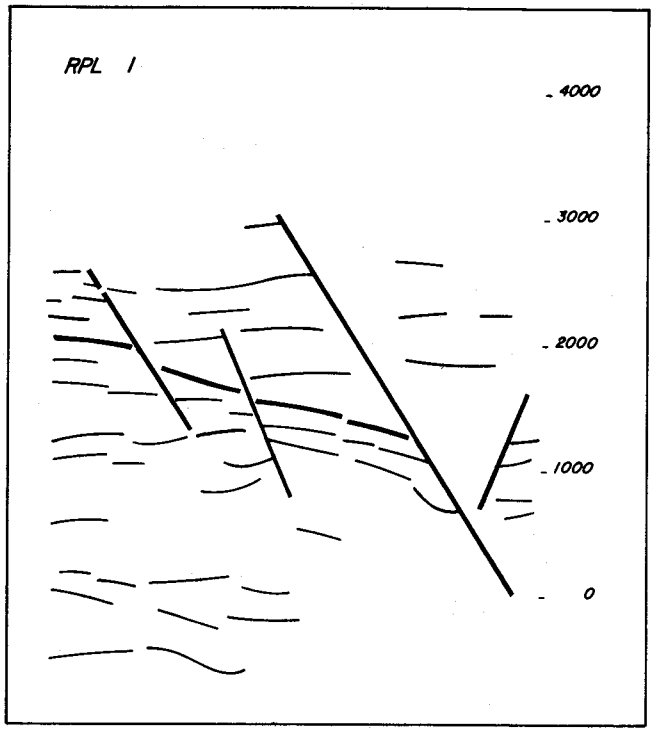


Figure 8

Fig. 8. The final result is the geologic section or model derived from the seismic data.

Design by Sue Angelon, Tucson, Arizona.

DERIVATION OF SEISMIC SECTIONS

The interpretation of any geologic surface (seismic discontinuity) is based on the strength, configuration, and continuity of seismic events as recorded on a seismograph during field shooting. The accompanying figures illustrate the development of seismic data from raw field records to an end product of meaningful geologic information. This sequence of information was obtained from a typical seismic reflection survey.

Identification of a particular seismic event with the surface of a particular geologic unit requires close cross correlation of the event with the velocity data. Further identification and interpretation is conducted on the basis of depth sections that are derived from the time-section playbacks.

The reliability of seismic interpretation depends partly upon the homogeneity of the rock units. Any heterogeneity, particularly along the traverse direction, will affect both corrections and velocity analyses. In addition, errors in evaluating the average velocity will have a directly proportionate effect on the interpreted depth of a particular event.

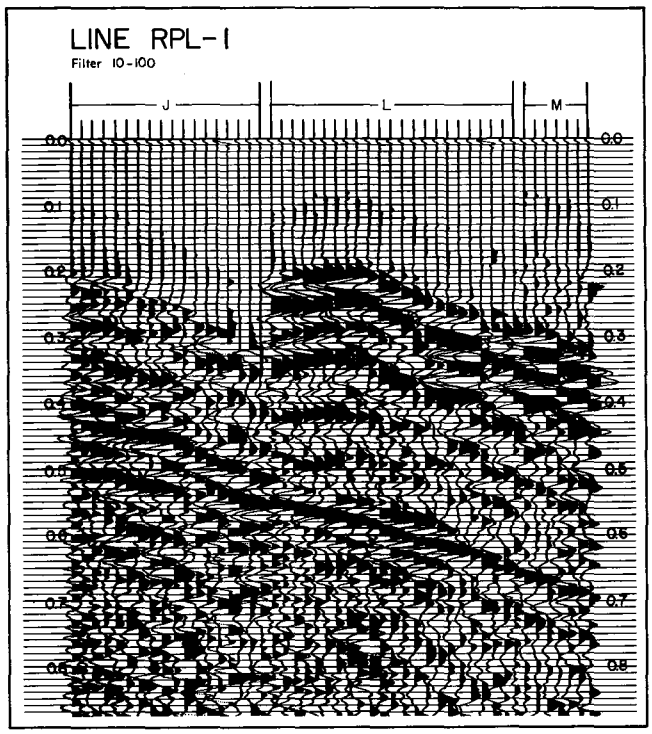


Figure 3

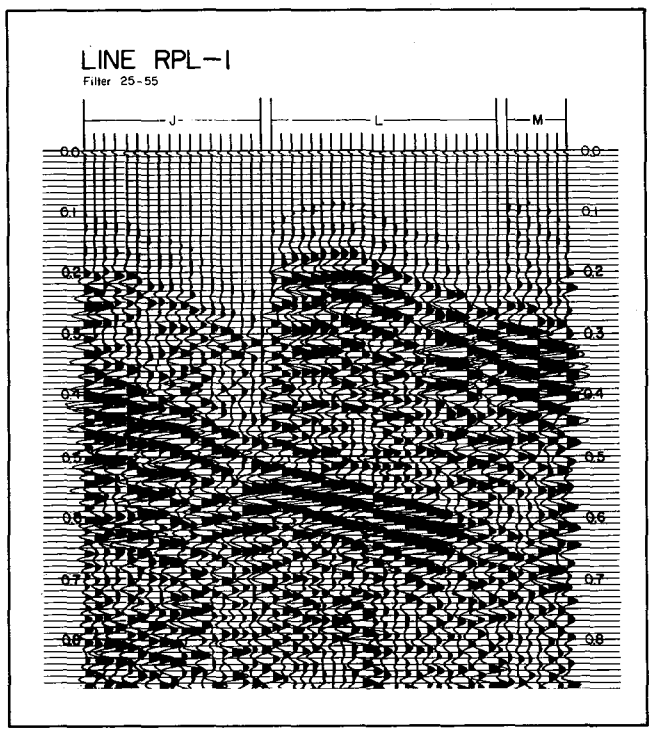


Figure 4

Figs. 3 & 4. During field shooting, at the same time the sensors are recording the "paper records" just described, they are also producing magnetic tapes of the same records. The magnetic tapes are later computer processed to get the results shown here. As with the paper records, seismic information is depicted in time domain (in terms of the travel time of the seismic waves). These profiles are a single recording of events, seen through two frequency "windows": 10-100 cps and 25-55 cps. The 25-55 cps window shows the seismic discontinuities more clearly and more uniformly; hence these are used in constructing the geologic model. The 10-100 cps passband is used to detect frequency and amplitude irregularities. Such characteristics can be used to further interpret geologic features.

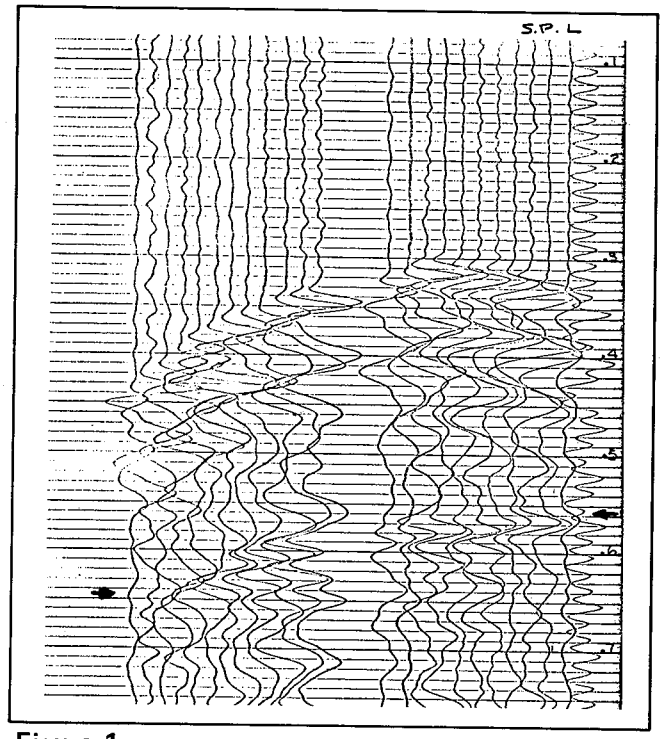


Figure 1

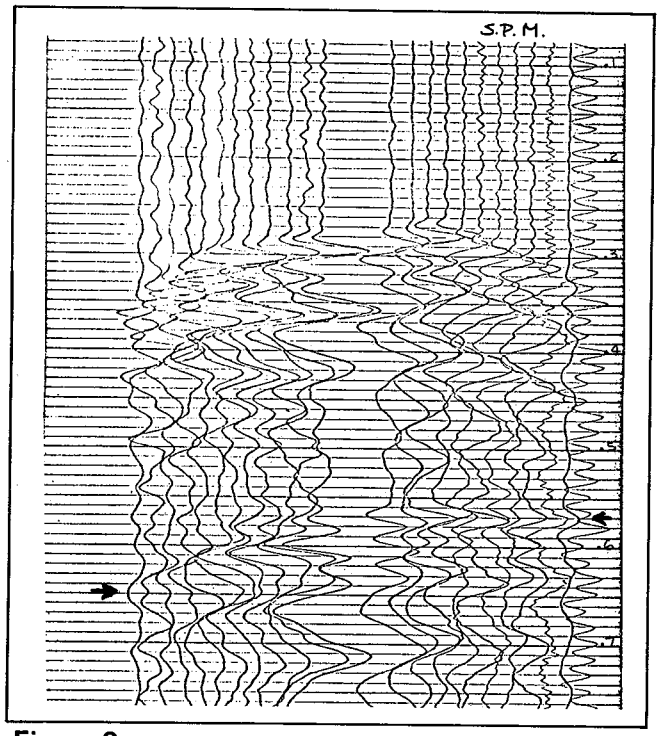
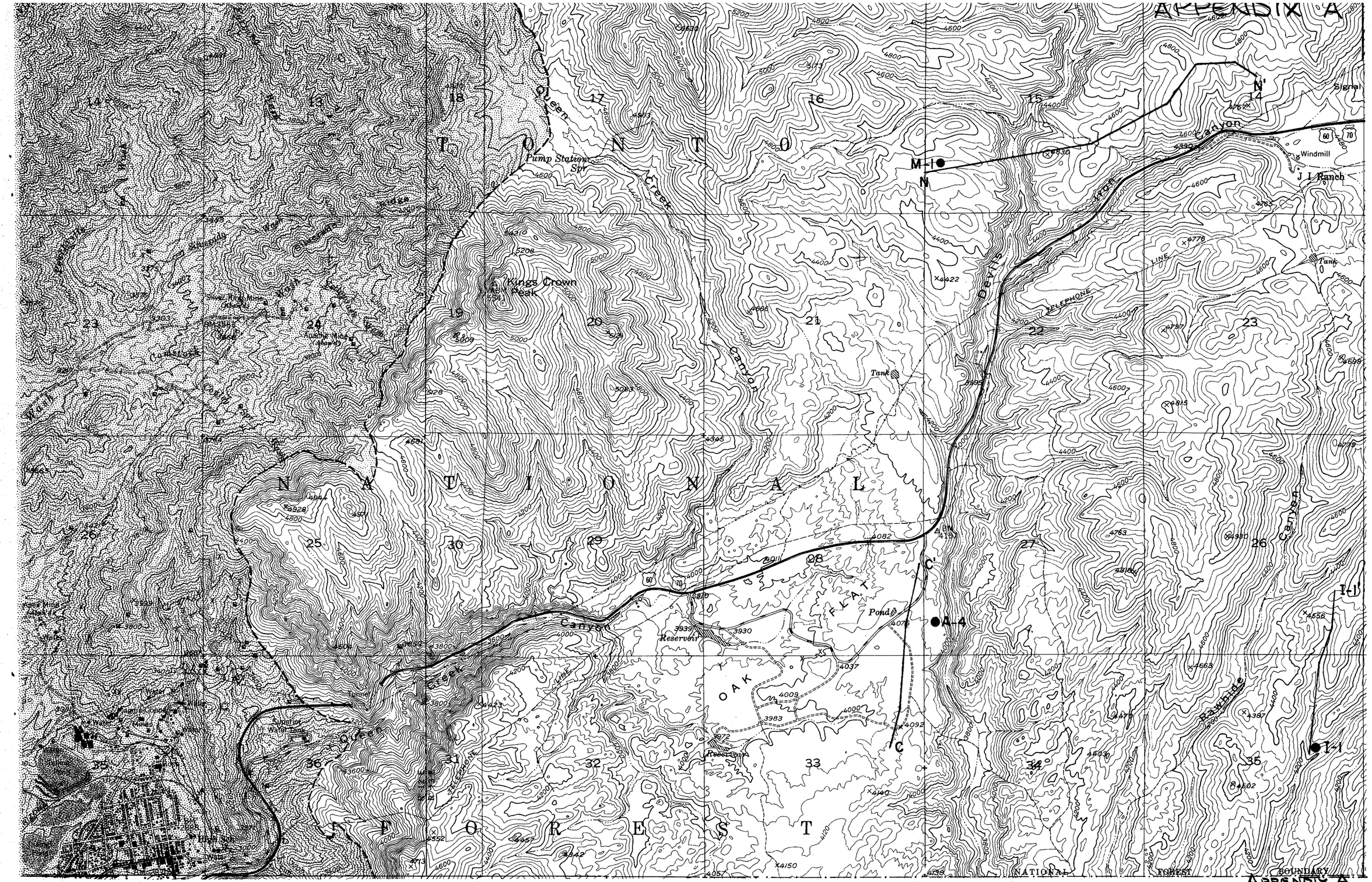


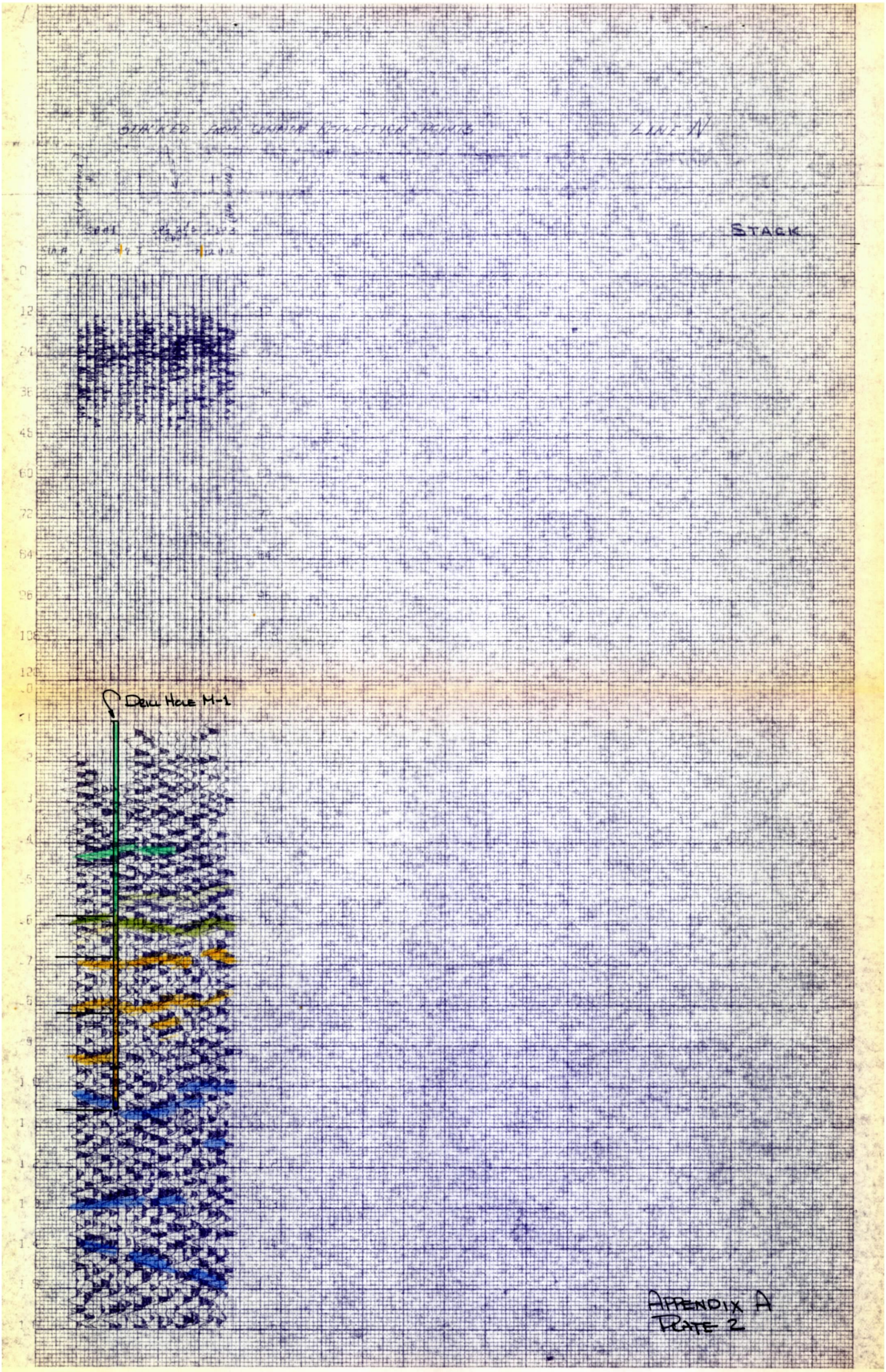
Figure 2

Fig. 5. The time template shown next is derived by tracing seismic events from the filtered seismic records, such as the RPL-1 profile of Fig. 3.

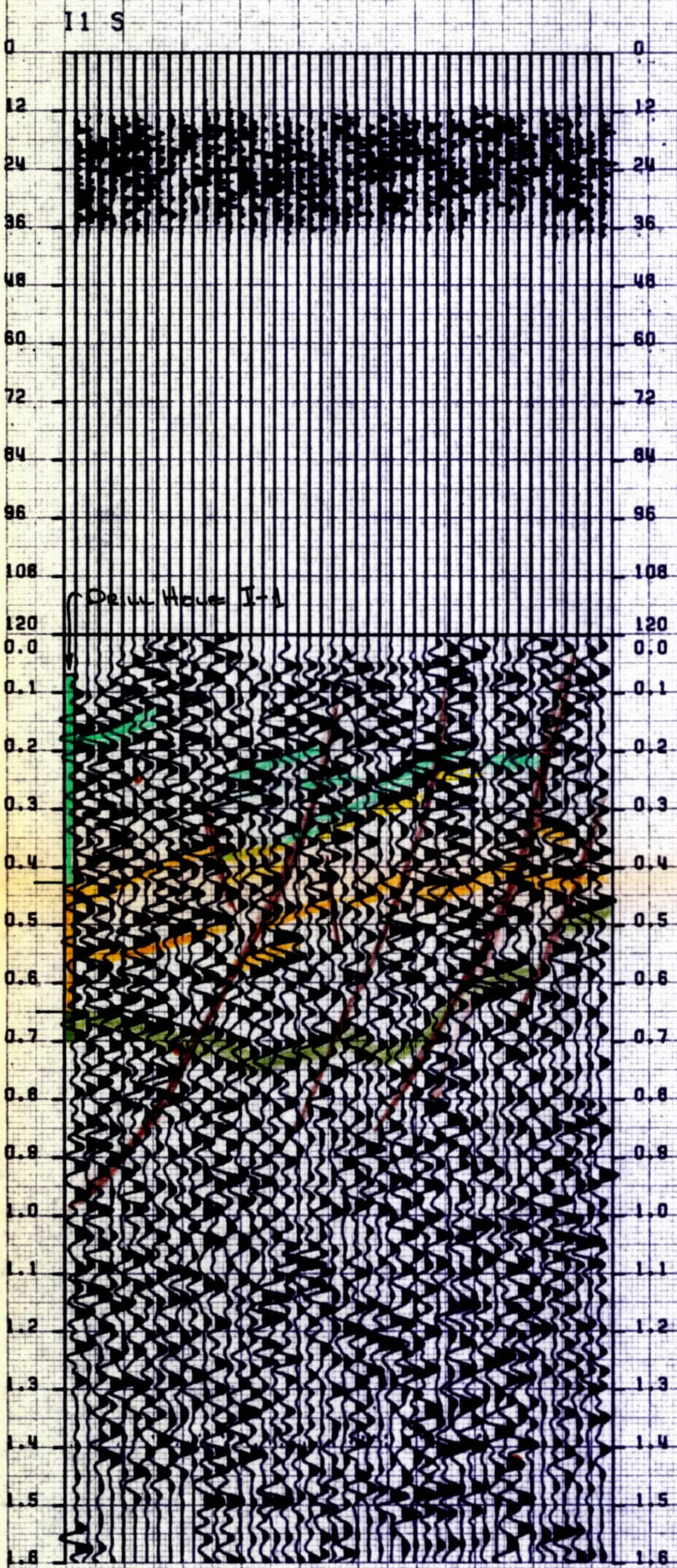


LOCATION MAP

APPENDIX A
PLATE 1


STACK
LINE N
DRILL HOLE M-1
0
12
24
36
48
60
72
84
96
108
120
APPENDIX A
PLATE 2

JOB 209 LINES 2 (I-1) ~~& 3 (SEC 4)~~



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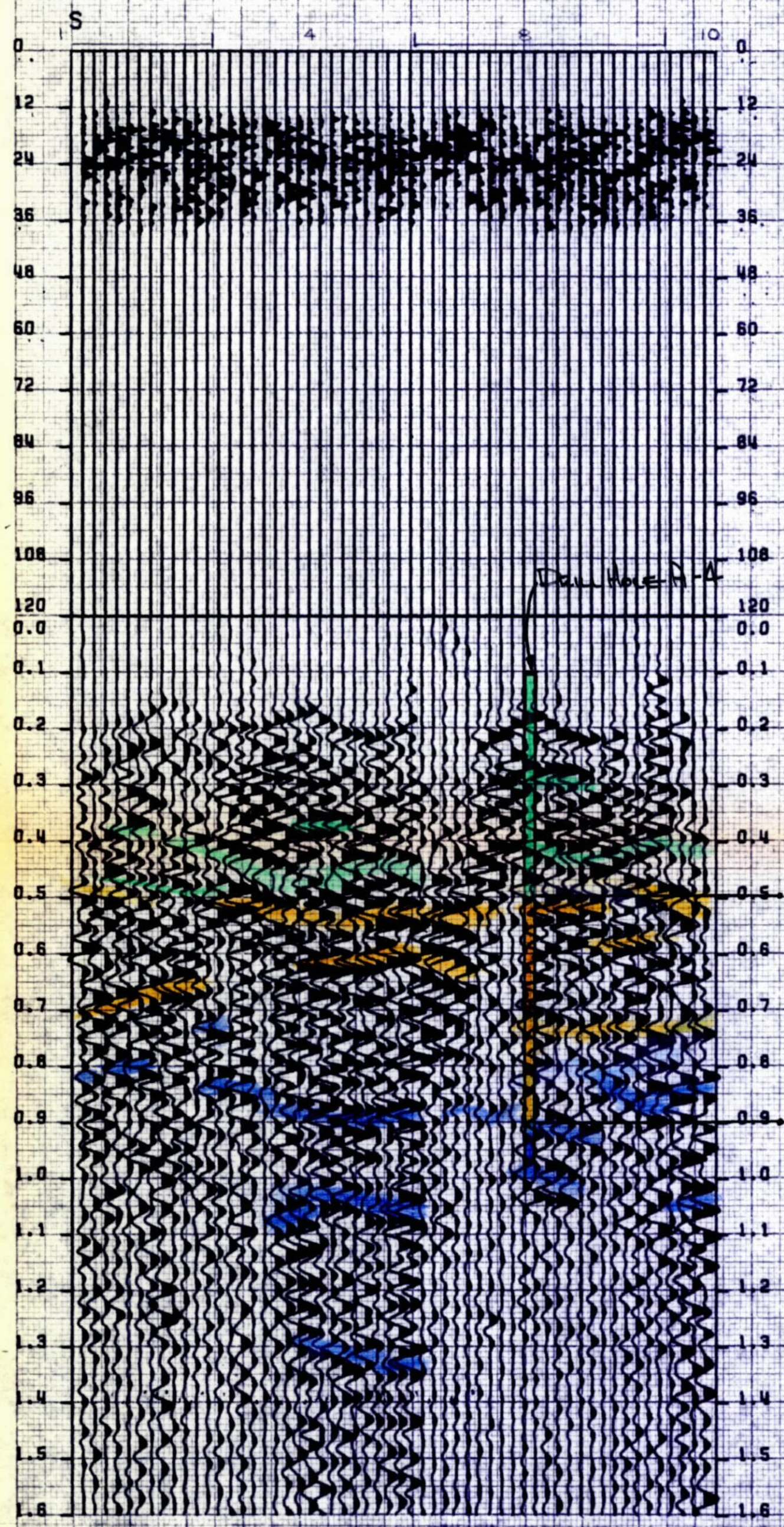
Appendix A
Plate 3

JOB 209-174 LINE C MARGARET

Run # 1



Appendix A

Plate 4

TAB

Envelope 2

Appendix B

LINE N

VELOCITY PROFILE SHOT POINT 1

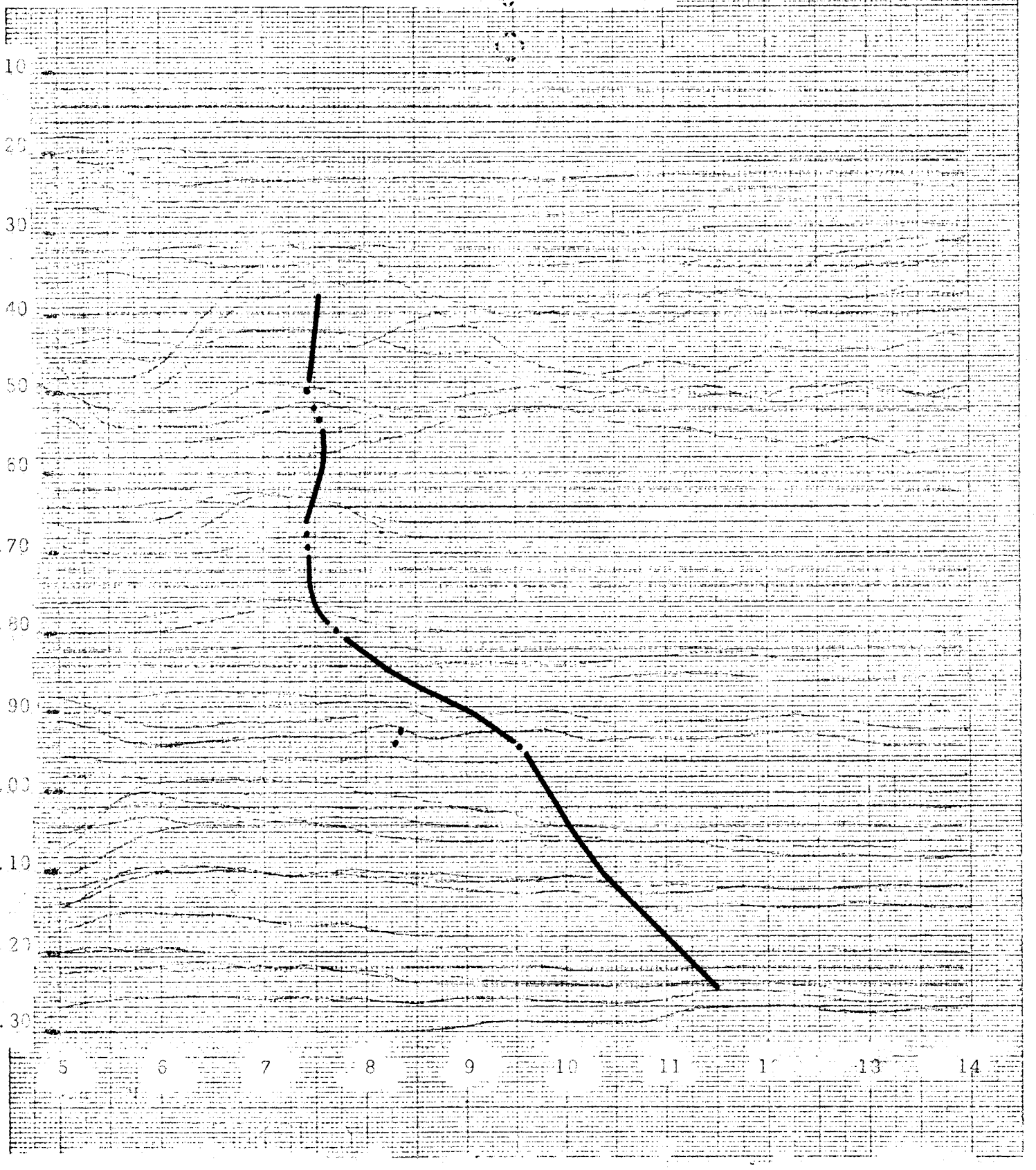


PLATE 1

LINE N
VELOCITY PROFILE SHOT POINT 2

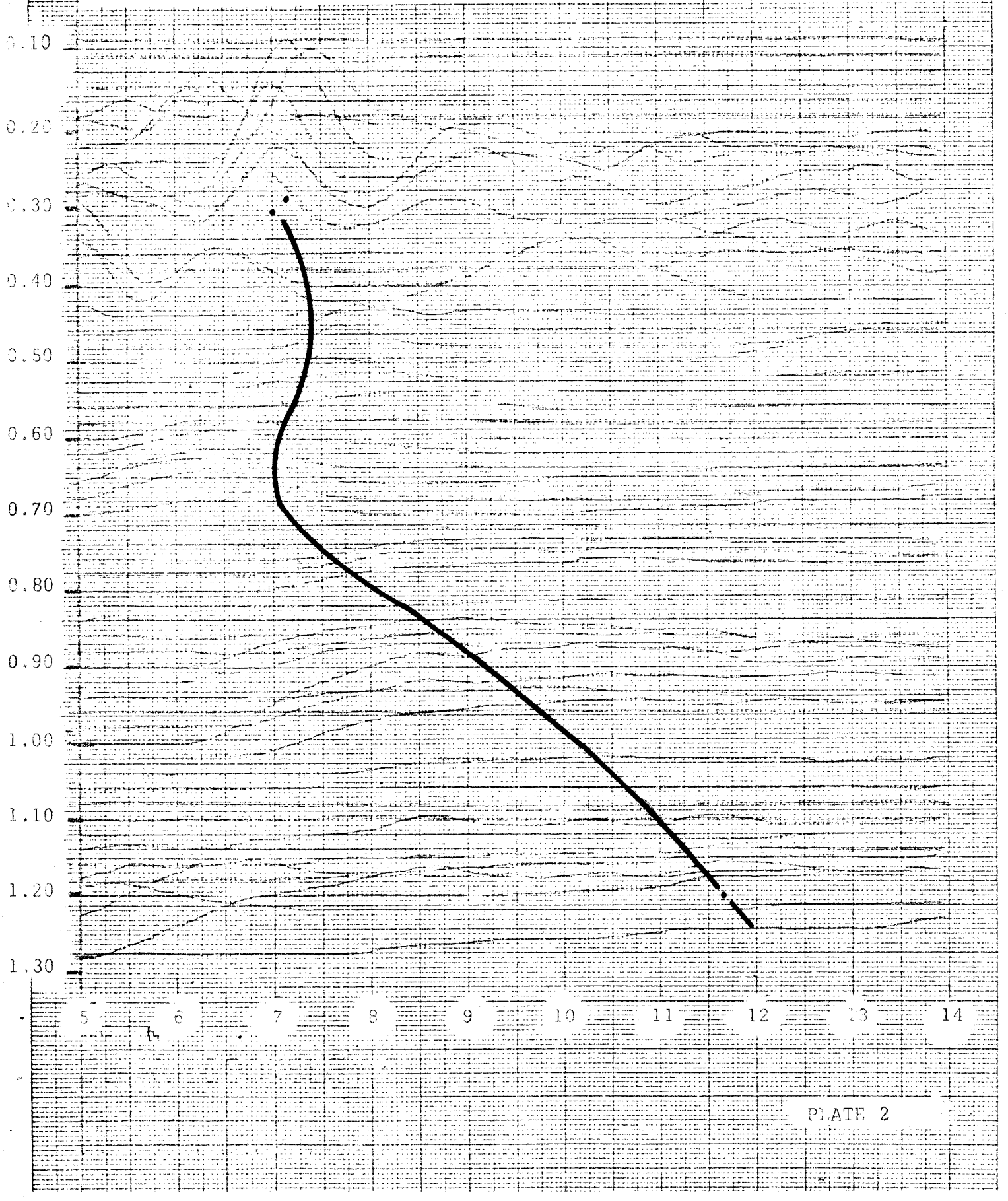
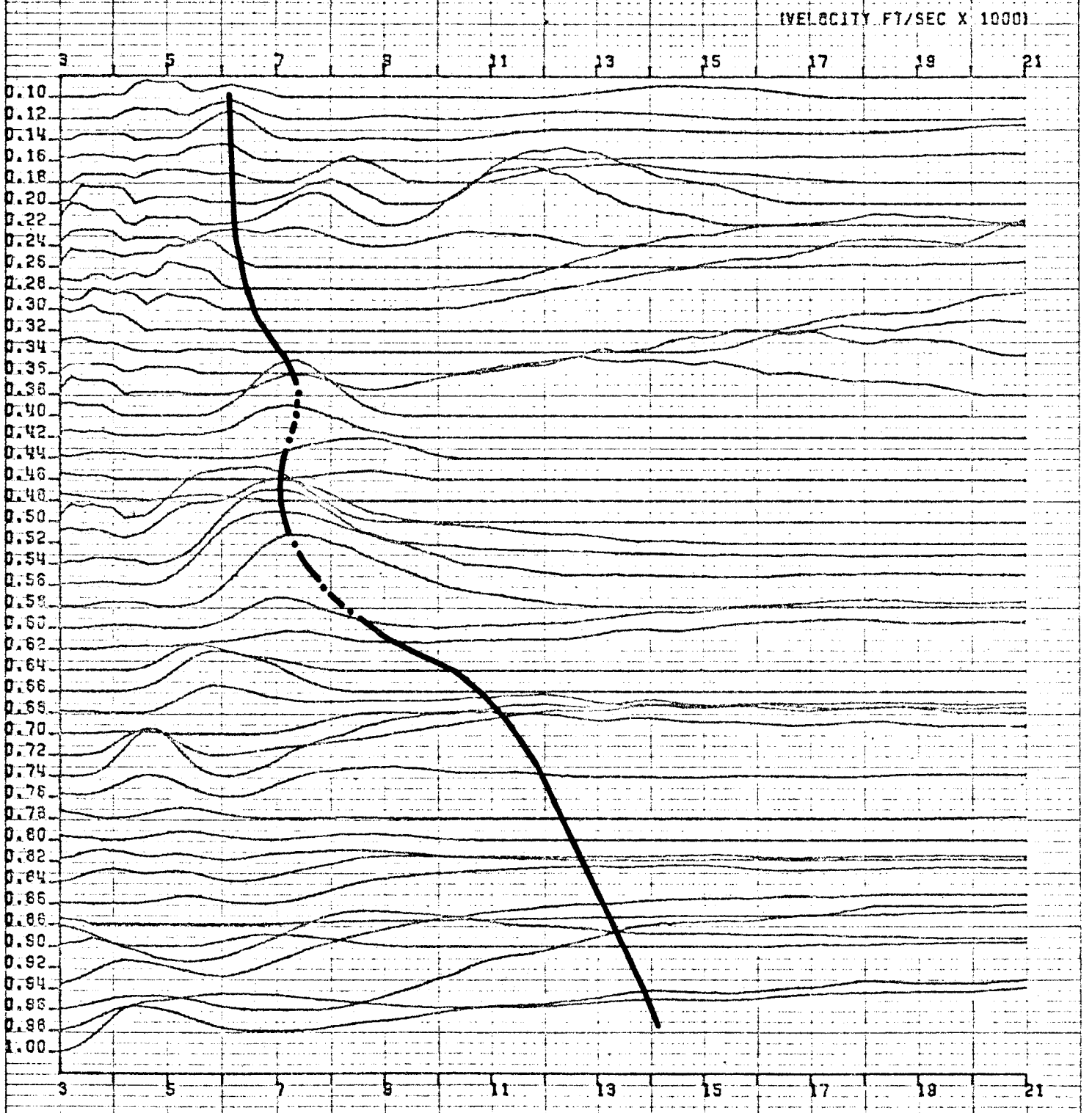


PLATE 2

VELOCITY PROFILE SHOT POINT 1 N

LINE I-1



LINE - I-1 - JOB 209

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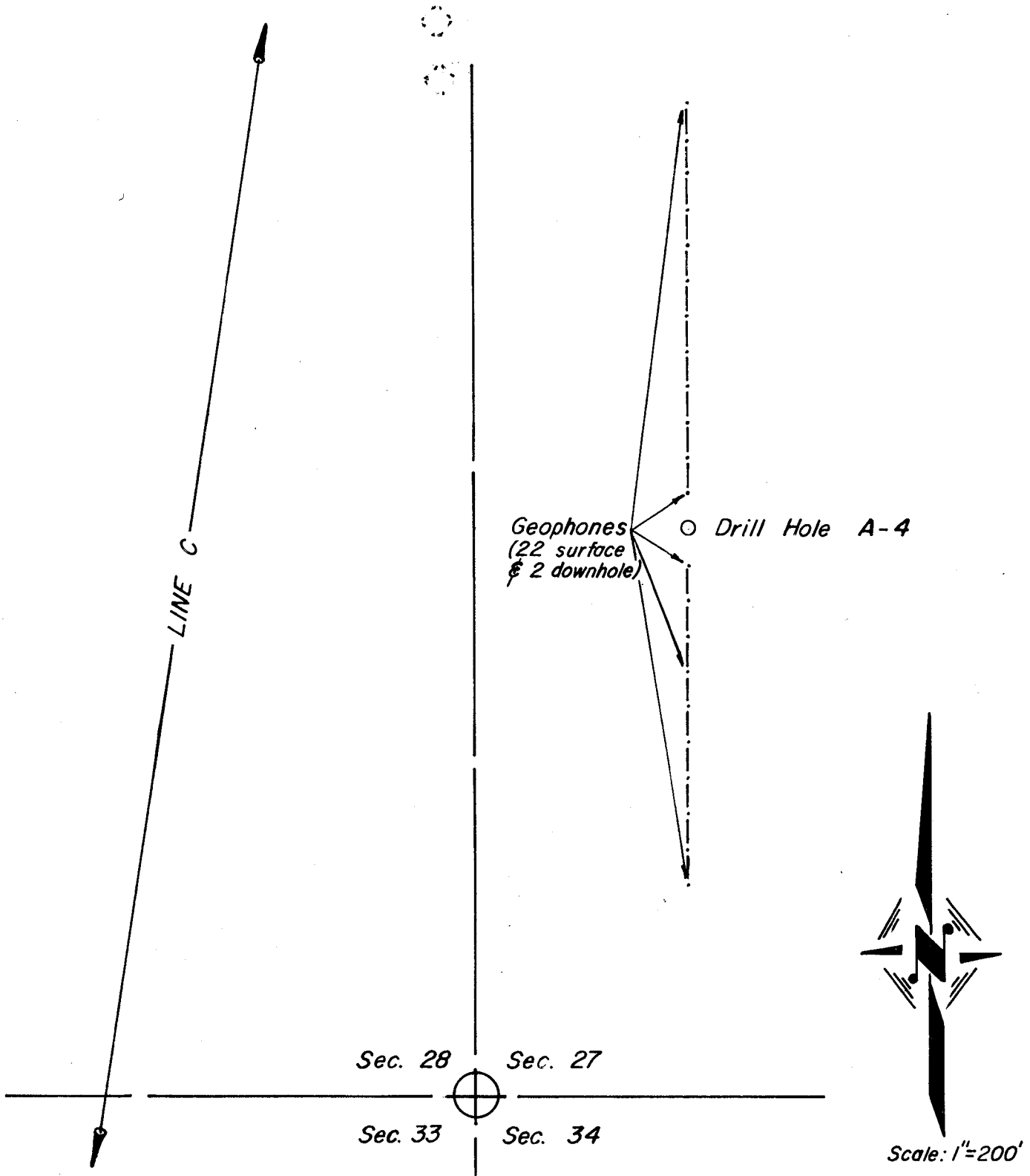
PLATE 3

TAB

Envelope 3

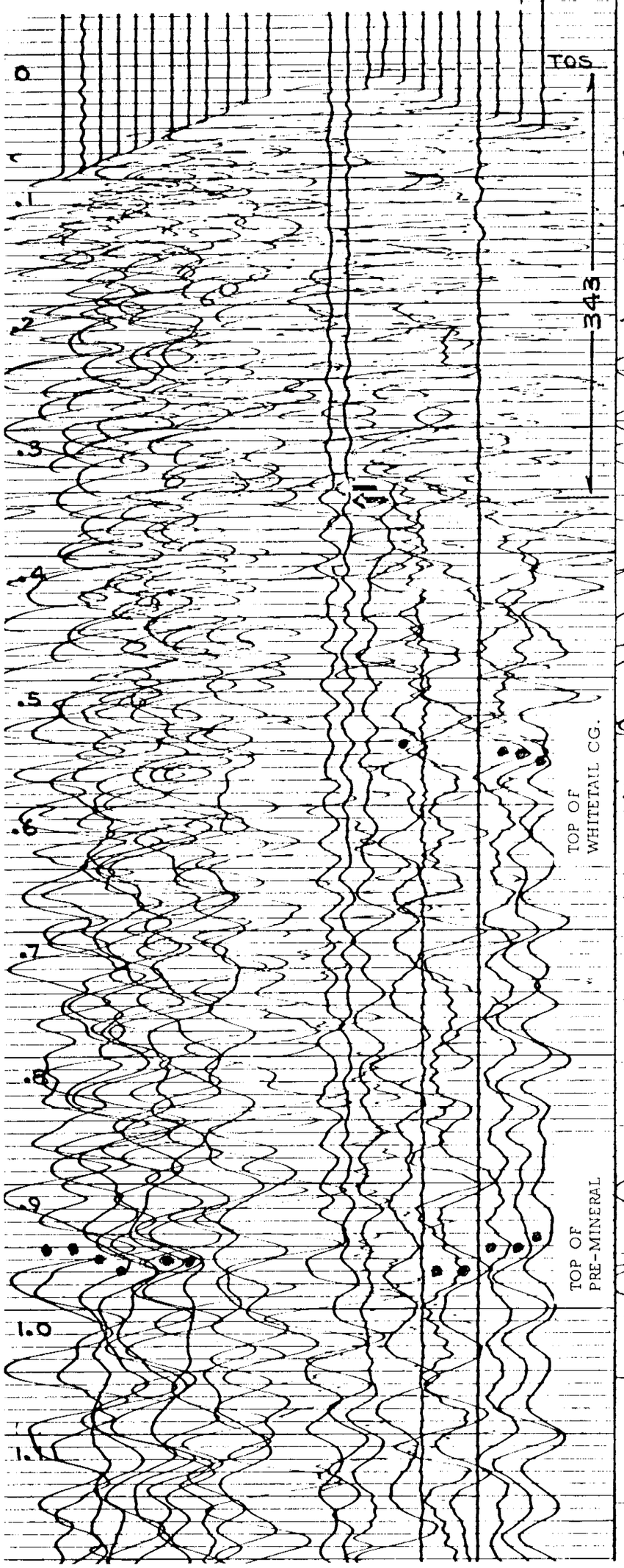
Appendix C



APPENDIX C
PLATE 1
Location Map

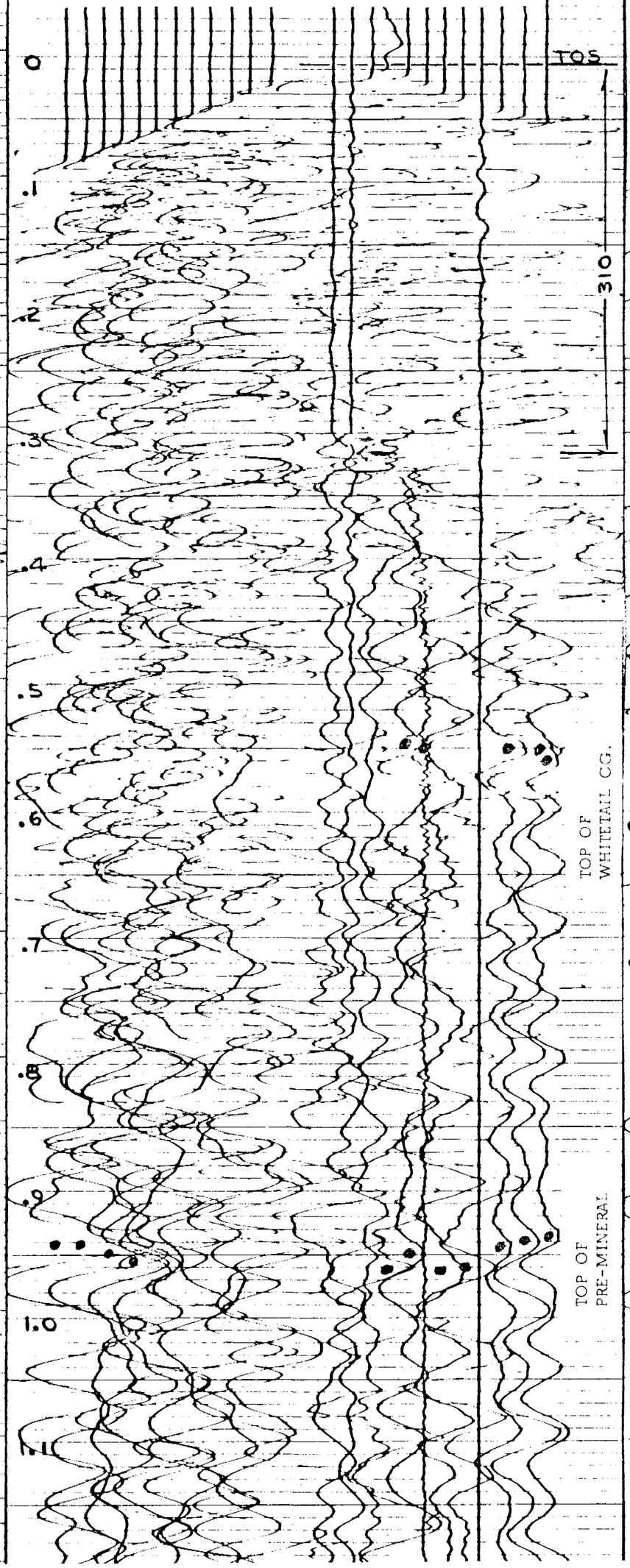
209 DOWNHOLE -- A-4
SHOT NO. 5
COLLAR OF HOLE at Sta. 550 feet
Total depth of hole = 6,900 ± feet
Sensor No. 1 at 4,490 feet = 343.0 ms
Sensor No.2 at 4,340 feet = 334.5 ms
Interval between sensors: Depth = 150 feet
Time = 8.5 ms
Velocity = 17,600 fps

SHOT POINT at Sta. 400 feet
Depth of S.P. = 8 feet
Charge size = sticks of 60%



209 DOWNHOLE -- A-4
SHOT NO. 6
COLLAR OF HOLE at Sta. 550 feet
Total depth = 6,900 ± feet
Sensor No. 1 at 3,990 feet = 310.0 ms
Sensor No. 2 at 3,840 feet = 301.5 ms
Interval between sensors: Depth = 150 feet
Time = 8.5 ms
Velocity = 17,600 fps

SHOT POINT at Sta. 400 feet
Depth of S.P. = 8 feet
Charge size = sticks of 60%



209 DOWNHOLE -- A-4
SHOT NO. 7
COLLAR OF HOLE at Sta. 550 feet
Total depth of hole = 6,900 ± feet
Sensor No. 1 at 3,640 feet = 284 ms
Sensor No. 2 at 3,490 feet = N.R. ms
Interval between sensors = 150 feet
SHOT POINT at Sta 400 feet
Depth of S.P. = 8 feet
Charge size = sticks of 60%